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Developing a Laboratory Curriculum for Physics I

Paula Tracki Lawrence

University of North Florida

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DEVELOPING A LABORATORY CURRICULUM FOR PHYSICS I

by

Paula Tracki Lawrence

A project submitted to the Division of Curriculum and Instruction in partial fulfillment of the requirements for the degree of Master of Arts in Science Education

UNIVERSITY OF NORTH FLORIDA
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Signature Deleted

Dr. Marianne Betkouski, Advisor

Signature Deleted

Dr. G. Prichard Smith, Committee

Signature Deleted

Dr. Elinor Scheirer, Committee
DEVELOPING A LABORATORY CURRICULUM
FOR PHYSICS I

Paula J. Lawrence
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ABSTRACT

This curriculum project reviews the current research on laboratory activity formats and their effectiveness. The literature concerning laboratory safety and teacher liability is also reviewed.

The revision of Florida state high school science requirements is presented and the curriculum developed corresponds to these revisions. The project includes laboratory activities that correspond to the course student performance standards as designated by the state of Florida for the Physics I course and strives to aid teachers in fulfilling the 72 hour laboratory time requirement to meet eligibility requirements for additional state funding.

The criteria for selecting activities and materials are also included in this project. A sample evaluation form is included, as well as a summary of these teacher evaluations of the developed curriculum.
Chapter 1

INTRODUCTION

During the past few years, the Florida Legislature has been revising the educational curricula and requirements for high school graduation. The general requirements for high school graduation for the 1984-85 and 1985-86 school years are the successful completion of a minimum of 22 academic credits in grades 9 through 12. These requirements include 3 credits in science. Beginning in the 1986-87 school year and each year thereafter, the minimum number of credits required for graduation is 24 in grades 9 through 12. These requirements include 3 credits in science with each course having a laboratory component. The State is proposing that the laboratory component consist of 72 hours of laboratory-related activities per course per school year out of the minimum requirement of 150 hours of bona fide instruction. These time guidelines are to encourage schools to apply for "high-cost" laboratory money. This legislation gives schools who meet the 72 hour time requirement extra funding for science laboratory classes. The time requirement must be well documented for a school to comply. The laboratory
component proposed by the State and which is eligible for extra funding constitutes 48% of all instructional time.

The new laboratory time requirement proposed by the State could have serious consequences for Florida schools. Teachers who teach 2 or more different courses per day will especially feel the time constraints. Teachers find courses with a laboratory component to be very time-consuming. Laboratory activities require time for preparation which can only be conducted at the facility site. This differs from the preparation of lecture material in that lecture material can be prepared away from the facility site and well in advance to when needed. Moreover, after a teacher has acquired the necessary equipment and supplies necessary for an activity, time is needed to familiarize the students with the uses and procedures of the equipment. After an activity has been completed, there is also the time required to store equipment and materials, check for broken equipment, and dispose of waste. These are also on-site activities for the teacher. The time problem intensifies with each different course taught because each course has a different curriculum that the laboratory activities should match.
If more science courses are required for graduation, then classes might be larger to accommodate this. Since the State requires that the science courses offered must have a laboratory component, then it is likely there will be more students present in a laboratory classroom. Large science classes present problems for teachers. The more students present, the more likely an accident will occur. There is a management problem involved, also. It is difficult to observe large numbers of students performing hands-on activities simultaneously. Many of these classes will be courses that are required for graduation and will likely contain large numbers of immature students. The more students that are present and the more immature the students are as a group, the more likely an accident will occur. Accidents can happen and teachers need to be aware of their legal liabilities in relations to these accidents.

In addition to management problems with large classes comes the problems of supplies. The more science courses being offered to accommodate the extra science credits required by the State, the more laboratory activities that will be required. Additional laboratory activities will require additional supplies to support them. This
places a financial burden on the schools and their districts. Supplies will need to be replenished, additional equipment will be needed to accommodate the additional activities and students, and broken equipment will need to be replaced.

Recently, the Florida Department of Education has developed criteria for each science course which can be offered by a secondary school. The laboratory activities currently experienced by Florida high school students vary from school to school and from teacher to teacher. Laboratory curricula will need to be developed that correspond to the new State-mandated performance standards. These curricula will also need to meet the time requirement for any school districts desiring to apply for the "high-cost" laboratory funding.

The purpose of this project is to develop a laboratory curriculum for the Physics I course offered in the state of Florida by secondary schools. This curriculum will correlate with the State-mandated performance standards in Physics I, will emphasize writing skills that current research indicates our students lack, will require little if any expensive equipment so as to ease the financial strain on school districts, and will meet the 72 hour laboratory time requirement for schools
desiring to apply for additional state funding. The
development of the laboratory curriculum for the Physics
I course may also suggest approaches to the development
of laboratory curricula for other science courses re-
quired in Florida.
DEFINITION OF TERMS

1. **carcinogen**: a substance suspected of causing cancer

2. **compensatory**: designed to compensate for a lack of skills in a specific area; involves one-on-one instruction

3. **consummable**: referring to materials that are not reusable

4. **"cookbook" laboratories**: laboratory activities in which students follow step-by-step instructions and fill in answers to pre-determined questions

5. **curriculum**: a list of topics to be covered in a course; also includes detailed explanations of how topics are to be covered

6. **inquiry**: a type of activity in which students are presented a problem or question and the students determine the steps to be taken in answering the problem or question

7. **laboratory activity**: a learning experience in which students manipulate equipment and collect data

8. **secondary**: referring to grades 7-12 or high school

9. **teratogens**: substances suspected of causing malformations in embryos

10. **vocational**: referring to job-oriented classes; job skills are taught in these courses
Chapter 2

REVIEW OF RELATED LITERATURE

This review of related literature discusses various aspects of laboratory or hands-on activities in secondary school science classrooms. These aspects include the importance of laboratory activities, a brief description of laboratory activity formats, a comparison of the two most commonly used formats, and views questioning the importance of laboratory activities. Also discussed are safety practices and procedures concerning laboratory activities, legal liabilities of teachers involved in laboratory accidents, and a discussion of the new science standards in the state of Florida.

These aspects of laboratory activities are included because they are the major issues relating to science laboratory activities and are currently a major concern of science educators. They should also be a major concern to teachers as these issues directly concern science teachers.

Though the majority of science educators strongly stress the importance of laboratory activities, school districts can create a valid case for eliminating these
activities in our schools (Swartz, 1979). Some reasons given by Swartz (1979) that support the elimination of laboratory activities in secondary schools are that teacher demonstrations are more effective, students frequently obtain incorrect results from their own experimentations, laboratory rooms without equipment could be partitioned off to create two classrooms from one classroom in schools where space is limited, budgets to science departments for consummable supplies could be decreased, and the time spent on repair and maintenance of equipment in science rooms could be practically eliminated. School districts could present a very effective case, from a financial as well as teaching effectiveness standpoint, to eliminate science laboratory activities entirely.

If some of our nation's school districts are supporting the elimination of science laboratory activities from our schools, many states in our country are not. An example of a state strongly emphasizing academic areas like science and math is Florida (Florida ASCD Task Force Report, 1983). In the past several years, the Florida legislature has been revising the requirements for high school graduation. These new requirements for graduation include 3 science credits or courses (Florida ASCD Task Force Report, 1983).
These science courses must also contain a laboratory component. Since the State Legislature is requiring more science courses for graduation and these courses should contain a laboratory component, other aspects of laboratory activities should be considered. These other aspects of laboratory activities directly affect teachers in their classroom performance.

A great deal of discussion about which goals are in fact better achieved through laboratory instruction rather than through other teaching methods has occurred (Lunetta, et al., 1981). Perez (1982) feels that the laboratory is the only way for students to become familiar with the process that characterizes the discipline of science. Researchers have not comprehensively examined the effects of laboratory instruction upon student learning and growth, but there is good reason to believe that laboratory activities are important in fostering understanding of certain aspects of the nature of science (Lunetta, et al., 1981). It is also believed that laboratory activities promote intellectual and conceptual development, promote the development of positive attitudes toward science, and are important in the development of certain problem-solving skills (Lunetta, 1982).

Penick (1981) stated that the sheer number of
courses with laboratory components indicates that teachers must believe that they are essential. Hardly anyone disagrees with the idea of providing alternate forms of learning to emphasize concepts from lecture and texts (Penick, 1981).

Voltmer and James (1982) have named science as a strategic curriculum area in terms of the learning of all pupils. Science content coupled with science laboratory activities gives students a "lever" on manipulating and understanding their environment.

The effective use of the laboratory as a teaching device is very sensitive to teacher competence (Voltmer & James, 1982). Many teachers do not possess the laboratory teaching competencies necessary to operate laboratory-based instruction successfully.

For beginning teachers, the use of laboratory activities once a week can be frustrating and practically an insurmountable task (James & Crawley, 1985). In the past, it was assumed that teachers gained preparation skill for laboratory activities simply by experiencing laboratory activities in the courses required for their science majors. This assumption is invalid today and is the probable reason that the laboratory as a teaching tool in secondary schools has not been used to its fullest potential (Voltmer & James, 1982).
Recent efforts at various universities have addressed the need to provide laboratory teaching skills for preservice teachers (James & Crawley, 1985). Research has been conducted to identify the laboratory teaching skills needed to enable science teachers to be more effective in their science teaching (James & Crawley, 1985). As the data for the research was collected and analyzed, two implications emerged (James & Crawley, 1985). There exists a recognition that laboratory science teaching is an important part of science instruction and that science educators can and should provide instruction directed at improving the laboratory science teaching skills of both preservice and inservice teachers (James & Crawley, 1985). The dearth of literature on laboratory teaching skills points to the need for a careful description of this area of science teacher preparation (James & Crawley, 1985).

The 1980-81 Board of Directors for the National Science Teachers Association (NSTA) unanimously adopted the following statement regarding the place of laboratory experiences in science education: NSTA endorses the necessity of laboratory experiences for teaching and learning in science (Klein, Yager, & McCurdy, 1982). Adequate support for materials, equipment, and teacher time must be available for schools to maintain quality
science instruction (Klein, et al., 1982). Such a quality program is critical in today's age of science and technology.

Laboratory activities are common concrete experiences for students (Ivins, 1983). There are five different types of laboratory activities that each offer experiences necessary for developing concrete to formal thought processes in students (Ivins, 1983).

One type of laboratory activity develops skills such as measurement and observation. These types of activities do not require formal reasoning, but do teach important skills used in subsequent laboratory activities (Ivins, 1983).

A second type of laboratory activity verifies concepts or principles previously studied in a textbook or presented in a class discussion (Ivins, 1983). This type of activity states the problem for the students, predicts the results, and specifies the procedures.

A third type of laboratory activity is the guided discovery. This type of activity gives the students directions from the teacher but does not give the students the results or conclusions to expect (Ivins, 1983). This type of activity usually serves as an introduction to a topic where the type of activity previously mentioned follows the presentation of the topic.
A fourth type of laboratory activity is where the teacher presents the students with a problem and allows them to develop their own methods for collecting data (Ivins, 1983). This type of activity requires time, patience, and flexibility on the part of the teacher.

The fifth type of laboratory activity places the entire burden of the investigation on the students, who must formulate both the problem and the method of data collection (Ivins, 1983). This type of activity is a true research project and requires that students must be knowledgeable and skillful (Ivins, 1983).

When a shortage of equipment occurs or an activity requires dangerous chemicals, the laboratory activity may be demonstrated by the teacher. This is an adequate substitution for a laboratory activity but does not involve the students to the extent that a laboratory activity they actually perform does.

The two types of laboratory activities most traditionally used in secondary science classrooms are the open-ended laboratory activity and guided discovery activity. Open-ended laboratories are laboratory experiences for which unique, individual answers are found for each particular investigation. The format of the traditional labs calls for general answers to be obtained by students and recorded in completion or fill-
in-the blank worksheets (O'Shea, 1979).

Research in comparing the two most commonly used laboratory activity formats indicates that there are no significant differences between the two laboratory approaches for all the measures considered (O'Shea, 1979). A group of studies do indicate that "hands-on" activities do significantly instruct students in the use of the laboratory (O'Shea, 1979). Practical manipulation of laboratory materials and laboratory skills seem to be more effectively learned in the lab than by any other means but the assumption that cognitive learning is facilitated by laboratory-centered instruction has simply not been substantiated (O'Shea, 1979).

Recently, science educators as well as educators in other fields have expressed concern that the writing skills of students entering our nation's colleges are not what they should be (Steiner, 1982). This problem can be aided by one traditional activity in laboratory classes- the writing of the laboratory report (Pyle & Trammell, 1982).

Several difficulties are involved with science laboratory report writing. One difficulty is the general feeling by students that writing is only important in English and related areas (Davis & Matlak, 1978).
Another difficulty encountered in laboratory report writing is that most scientist and science teachers are seldom competent to grade writing (Brillhard & Debs, 1981).

These difficulties and others led most schools to begin using the "fill-in-the-blanks" format for expressing laboratory activity results. This type of report format replaced the more formal report which required students to record observations, categorize these observations, then draw conclusion based on the results recorded (Brillhart & Debs, 1981).

One school that initiated changes in their science curriculum to improve student writing skills was in Huntingdon, New York. The school district in Huntingdon observed that student performance on essay exams had suffered (House, 1983). The schools emphasized the inquiry method of learning and when comparing the results of students on state writing tests, some progress was observed (House, 1983). The progress was aided by students in science classes writing laboratory reports.

In addition to aiding writing skills of students, writing laboratory reports is a method for teachers to evaluate student progress. Writing laboratory reports ensures students' comprehension of material covered since students cannot successfully write about concepts
they do not understand (Brillhart & Debs, 1981).

Hands-on activities are still strongly emphasized by science educators and teachers are asking numerous questions about these activities (Rice, et al., 1981). The questions being asked concern safe practices and procedures, legal liabilities in the classroom, and teachers' liabilities for the many possible, and sometimes unavoidable accidents that can occur.

It has been recently suggested that short courses should be offered to help keep secondary science teachers current on safety issues (Nagel, 1982b). The need for these short courses is due to the broad scope of activity in school science laboratories.

The University of Colorado recently offered one such short course for secondary science teachers. The purpose of the course was to provide teachers with the background necessary to implement safety programs in their science laboratories (Nagel, 1982b). The program emphasized accident causation and control, reducing the risk of personal liability for students' injuries, producing and enforcing laboratory safety rules to be used in teachers' classrooms, fires and their prevention, hazards of chemicals, the safe handling of chemicals, the modes of entry into the body of toxic chemicals, and safety precautions for commonly used types of equip-
ment like mercury thermometers (Nagel, 1982b).

In May of 1982, a popular home and family magazine published an article concerning dangerous chemicals in high school science laboratories (Nagel, 1982a). It listed 37 chemicals common to high school laboratories that are classified as suspected carcinogens and suspected teratogens or chemicals capable of producing malformations in embryos. While this was offered as general information for the public, it might have been more effective if it had been distributed to the people who really need to know about what chemicals are in our schools—the science teachers who use them (Nagel, 1982a).

Classroom safety has always been a concern of classroom science teachers but most would admit to a greater concern at the present time (Rice, Brown, & Strope, 1981). Revelations in the past ten years about the dangers of working with certain substances and equipment have made teachers wary (Rice, et al., 1981). Even commonly used preservatives like formaldehyde for biological dissection specimens have been mentioned as suspected carcinogens.

As the rise in the numbers of lawsuits involving teachers has increased, so has teacher awareness (Rice, et al., 1981). Teachers have become increasingly aware of the major safety issues of today.
School science laboratories are active sites of learning. They are also sites of potential danger from fire, poisons, explosions, noxious fumes, and caustic chemicals (Jones & Llewellyn, 1977). Because the students working in these school laboratories frequently exhibit high spirits and lack of caution characteristic of the young, it is imperative that educators communicate to the students the potential hazards of the laboratory activity and the precautions necessary to make the laboratory work safe and effective (Jones & Llewellyn, 1977).

An easy means by which educators could improve laboratory safety would be by adopting a universal system of safety symbols. To be maximally effective, the system would identify the hazard, the degree of danger, and the methods of handling (Jones & Llewellyn, 1977). The system would be more effective if symbols were combined with words because it surmounts the problem of word recognition caused by age, poor reading skills, or language difficulty (Jones & Llewellyn, 1977).

It is the teacher's responsibility to stress safety plainly and as often as necessary. Complacency is a problem but so is ignorance of safety techniques or potential hazards (Shebesta, 1977). Few science teachers have had any formal safety training and must rely upon
written precautions, experience, and common sense. With
the increasing evidence, for example, on the toxicolo-
gical effects of exposure to certain substances, science
educators cannot afford a catch-as-catch-can approach
to safety awareness (Shebesta, 1977).

Science educators must realize that they are working
in an environment that presents dangerous situations.
Science teachers must also be continually alert to
eliminate hazards in their laboratory classrooms (Shebesta,
1977).

What standard of conduct must a teacher legally
meet in order to avoid liability if a student is injured?
The law that applies to teachers, the law on negligence,
is the same law that generally concerns the conduct of
all individuals in our society (Joye, 1978).

The courts demand that science educators give
safety the importance it deserves. Why? Because
teachers can be sued if ignorance is deemed to consti-
tute negligence for a student's well-being (Shebesta,
1977).

State-by-state differences in laws exist and it is
imperative that teachers are aware of these differences
(Joye, 1978). The record reveals that courts recog-
nize that science teachers work in complex situations
and that they must rely, to some extent, on the maturity
of the students to conduct themselves in a proper and safe manner (Rice, et al., 1981).

The science teacher who remains in the classroom while experiments are in progress, who properly instructs students in the use of materials and equipment, and who maintains a continuous safety education program should have little fear of liability (Rice, et al., 1981). Thus, teachers need not be unduly apprehensive.

On the other hand, Joye (1978) notes that litigation problems will get worse before they get better. In addition to using the procedures previously mentioned, teachers need to give serious thought to anticipating accidents and taking steps to prevent their occurrence. It is also time for teachers to start keeping complete records of maintenance work done, of safety lectures given, and of instruction provided in cases where students will be exposed to dangerous chemicals or other materials (Joye, 1978).

Florida science teachers are probably more in need of information on safety and other major issues than other science teachers. The Florida legislature has recently been revising the academic curriculum for high school students and one area that has undergone major revision is secondary science.

A report presented in the spring of 1983 by the
Florida Association for Supervision and Curriculum Development (FASCD) to its Executive Council predicted the probable outcomes of the new legislation by the state of Florida (FASCD Policy Task Force Report, 1983). The new legislation requires all high school students to complete 3 credits in mathematics and 3 credits in science out of a total of 24 credits for graduation.

The new legislation forecast effects in 5 areas: students, curriculum, staff, resources, and control. The forecasts were based on data from a survey of 4 school districts in Florida that represented a cross-section of Florida's population.

Four groups of students were predicted to be affected by the new legislation (FASCD Policy Task Force Report, 1983). The first group, which comprised 48% of the students sampled, are the college-bound students. These students generally take 3 credits of math and science presently so the impact of the proposed change will probably be minimal.

A second group of students predicted to be affected are the vocationally-oriented students (FASCD Policy Task Force Report, 1983). These students comprised 43% of the students sampled. These students generally take 2½ years of science and 2 years of math. The impact on these students is also predicted to be minimal.
because, along with the additional requirements for graduation, there is an additional hour of school required. This additional hour of school allows the vocationally-oriented students to take the academic classes required and still have time in their class schedule for vocational classes.

A third group of students forecasted to be affected (FASCD Policy Task Force Report, 1983) are the general students. These students comprised 19½% of the students sampled. These students generally take 2½ years of math and 2 years of science. The new requirement for additional math and science credits necessitates more advanced courses in both areas. One possible impact is a larger number of students in the science and math courses in the college-bound program or an increase in the number of student dropouts.

FASCD (1983) predicts that the new requirements will also affect curriculum. Students will have fewer opportunities to study in other areas. Existing college preparatory math and science courses are likely to be too difficult for the bottom 50½% of a student body so new courses will need to be developed to meet the needs of these students.

FASCD (1983) also predicts that the increased math and science requirements will have a major impact on the
supply of teachers. Math and science teachers are already in short supply as the numbers seeking employment outside education increase yearly.

Requiring 3 science credits will necessitate the addition of science laboratories to existing facilities. Under the new requirements, additional laboratories will be needed at an estimated cost of $15,000 each. The new requirements will have a major financial impact on our school districts.

The conclusion of the FASCD study was that the impact of requiring 3 credits in math and 3 credits in science will decrease the achievement of the college-bound students (FASCD Policy Task Force Report, 1983). One cause for the decrease in achievement will arise when additional math and science teachers, many of whom will not be qualified, are employed. This could produce an overall effect of decreasing the caliber of math and science teachers in Florida high schools.

Neither time nor provisions have been made to develop new courses for the non-college-bound students. None of these students will be assigned to the traditional college preparatory courses. This could result in diverting teachers from working with the college-bound students as the non-college-bound students will require extra help to master the subjects.
School science laboratories are already ill-equipped to meet the needs of the college-bound students. Spreading scarce resources further to meet the new state requirements can only weaken the college preparatory program (FASCD Policy Task Force Report, 1983).

In science education as elsewhere today, funds are short and time more so. It is thus imperative that laboratory activities be selected to enhance our teaching goals (Lunetta & Tamir, 1979). The purpose of this project is to develop a laboratory curriculum that meets the teaching goals as stated by the state of Florida for Physics I and take into consideration financial and many other issues already mentioned.
Chapter 3

PROCEDURE

The purpose of this project is to develop a laboratory curriculum for the Physics I course offered in Florida secondary schools. The state of Florida has mandated the performance objectives each secondary science course should cover during an academic year. This laboratory curriculum will correspond with the course student performance standards for Physics I as designated by the state of Florida. It is assumed that the curriculum for the laboratory component of a secondary science course is a reinforcement of concepts already studied. The laboratory curriculum for the Physics I course will strive to aid teachers in selecting laboratory activities to correlate with the subject matter covered and to meet identified performance standards, to utilize inexpensive equipment when possible, and to aid schools in meeting the 72 hour time requirement for laboratory activities when seeking extra state funding.

The content of the Physics laboratory curriculum will be selected from various science laboratory activity books, science textbooks, and science education magazines.
The content will strive to meet the majority of the State-mandated performance standards and will be organized in the sequence in which the State-mandated performance standards are presented. The approach to organizing the laboratory curriculum is designed to facilitate the location of various laboratory activities by the teacher; since most Physics textbooks do not agree in the sequence of topics covered, organizing by the State-mandated performance standards can provide a common frame of reference.

The learning experiences or laboratory activities themselves will be organized in such a manner that the teacher utilizing the curriculum can select activities according to the teaching model preferred by the teacher. Many teachers feel comfortable with a programmed instruction model where the students test outcomes for objectives previously studied. The model does not involve any questioning on the students' parts; it merely reinforces concepts already discussed.

In this programmed instruction model, the teacher is responsible for selecting materials and monitoring student progress throughout the activity. This type of activity is designed so that students follow step-by-step instructions, record observations, and answer questions based on the observations made. This method of instruc-
tion is also known as "cookbook" laboratory instruction. This model of instruction does have its critics but it does provide students with experience in making observations and drawing conclusions from those observations.

Another method of instruction, the inquiry method, will also be presented in the laboratory curriculum for those teachers desiring to use this method when conducting laboratory activities. The inquiry method confronts students with an event which they cannot explain or confronts students with a problem to be solved. In this type of instruction, the students must offer explanations or suggest theoretical formulations for the problem; then, they test their ideas. The role of the teacher in this method is to answer student questions and help guide their activity. The teacher does not provide or lead the students through a step-by-step procedure for the laboratory activity. The main criticism teachers note for this type of instruction is the time involved to conduct the activity. Students involved in this type of laboratory activity need sufficient to test ideas, make revisions, and test their revisions.

The type of method, whether it is programmed instruction, inquiry instruction, or a possible combination of the two, should be determined by the teacher using the curriculum. Activities presented will reflect the various
teaching methods so that the teacher may select the method most comfortable for him or her; this approach can ensure that the teacher derives the maximum benefit from the laboratory curriculum for the course.

The laboratory activities will be organized such that activities designed to teach students basic laboratory skills, such as length measurements, mass measurements, and time measurements, will be presented first. These types of skills will be presented first so that students will possess the prerequisite skills to complete the majority of the laboratory activities presented later in the curriculum. The activities will be designed to strive for an increase in difficulty level as the students progress through the laboratory curriculum.

The laboratory curriculum will also offer a variety of methods of evaluation of objectives by the teacher. Most of the methods will emphasize some form of report writing. Research cited in the review of related literature indicates that our nation's high school students demonstrate a lack of skills in report writing. Practice in such skills will serve to increase student job skills and will be of benefit to the students when writing reports in their college studies.

The laboratory curriculum developed in this project will be evaluated mainly by secondary science tea-
chers. Since an entire academic year is not available to test the curriculum with students, the main evaluation of the laboratory curriculum will be by other professionals. The professionals selected to evaluate this curriculum will be secondary science teachers. Those who will provide feedback are not only Physics teachers as there is a limited number of those professionals available and because it is assumed that all science teachers are capable of reviewing curriculum materials in all the major science areas.

The design of the laboratory curriculum is intended to provide a variety of activities from which teachers may select, a variety of teaching methods that can be utilized, and a variety of evaluation processes for the teacher to use. It is hoped that providing such variety will increase the usability of the curriculum and will offer teachers a degree of flexibility when using laboratory activities to enhance the State-mandated student performance standards for the Physics I course.
Chapter 4

TEACHING SUGGESTIONS

Chapter 5 of this project contains the laboratory activities selected to correspond with the state-mandated performance standards for Physics I. The activities are organized numerically according to the standard number under which the concepts are classified. The student performance standard numbers (abbreviated S,P.S. #) are located at the upper left on each activity. This is to enable teachers using the curriculum to locate activities for a specific concept readily.

Each laboratory activity, when applicable, has a choice of procedure for students to use. This allows teachers to select the procedure type, deductive or inductive, they prefer to use with their students.

The laboratory activities are written in the basic format of formal laboratory reports. It is hoped that the teachers using the curriculum will emphasize formal report writing for activities completed. Teachers may also devise a report sheet that contains just the data tables and results questions/calculations that the students may use in lieu of formal reports.
Chapter 5

PHYSICS I LABORATORY CURRICULUM
S.P.S. # 1

Gathering and Analyzing Data

Materials

5-8 jar lids (various diameters)
string
ruler

Procedure

Inductive:

1. Measure the diameter and circumference of each lid.

2. Plot the data on a graph, placing circumference on the vertical axis.

Data

1. Make a table to indicate the diameter and circumference for each lid measured.

Results and Conclusions

1. What is the mathematical equation you generally use to find the circumference of a circle from the diameter?

2. Calculate the slope of the line drawn on the graph.

3. How close is your slope to the constant in the equation in result #1?

4. Predict the circumference of a circle 10 cm larger than your largest diameter object.
S.P.S. # 1

Measurement

Materials

rulers
mimeographed sheets with diagrams

Procedure

Inductive:

1. Test your eyes as instruments for estimating lengths by using the diagrams below.

2. Judge whether \( \overline{AB} \) is greater than, less than, or equal to \( \overline{BC} \). Record your observations.

3. Judge whether \( \overline{DF} \) is greater than, less than, or equal to \( \overline{GH} \). Record your observations.

4. Now measure the lengths of each line segment mentioned in steps 2 and 3 and record.

Data

1. Make a chart recording all measurements and observations made.

Results and Conclusions

1. How did your judgement in step 2 of the procedure compare with the actual measurements?

2. How did your judgement in step 3 of the procedure compare with the actual measurements?

3. What does this experiment tell you about depending upon your eyes alone to obtain precise information about lengths of objects?
S.P.S. #1

Finding the Thickness of a Bean

Materials

100-ml graduated cylinder
dried beans
vernier caliper
metric ruler

Procedure

Inductive:

1. Measure the volume of some beans in a graduated cylinder. Then spread the beans in a single layer on the tabletop and arrange them into the smallest possible circle.

2. You have formed a cylinder with a height of one bean thickness. Measure the diameter of the circle. Repeat the procedure twice with different numbers of beans.

3. With a vernier caliper (or metric ruler) measure the thickness of 3 different beans.

Data

1. Make a table for the 3 trials having a column for volume and diameter.

2. Make a second table to record the radius and height of the beans in the 3 trials.

3. Make a third table to record the thickness of the 3 different beans in step #3.

4. In all tables, record the average for each quantity measured.

Results and Conclusions

1. Using the equation for the volume of a cylinder \( V = \pi r^2 h \) solve the equation for \( h \). Calculate for each trial and determine the average.

2. Determine and record the average thickness found by the second method.
3. Which method do you think gives the most accurate measurement of the thickness of a bean? Explain.

4. List some length and volume measurements that would be difficult to make directly.
S.P.S. # 1

Measuring Time

Materials

string
weight
clock with second hand

Procedure

Inductive:

1. Make a pendulum by hanging a weight from a string the upper end of which is fastened so that the weight can swing back and forth freely.

2. Adjust the string so that the pendulum is about 1.5 feet long.

3. Start it swinging through a small arc and, using a clock with a second hand, see how many vibrations it makes in 30 seconds.

4. A vibration is one complete swing forward and one complete swing back.

5. Repeat the experiment several times, keeping the arc of the swing small.

6. Record measurements made.

Data

1. Make a table of swing versus time for all trials.

Results and Conclusions

1. Determine from your observations how long it takes the pendulum to make one vibration during each of the trials.

2. Is your pendulum dependable as a means of measuring time?
Measuring Height Indirectly

Materials

- string or fishing line
- protractor
- meter stick

Procedure

Deductive: Using geometry, determine your height without actually measuring it.

Inductive:

1. Hold one end of the strong on the top of your head.

2. Have your partner extend the string to the floor in front of you.

3. Measure the length of the string from your head to the floor, the angle at which it meets with the floor, and the distance between your feet and where the string touches the floor.

4. Measure your height directly by standing against the wall.

Data

1. Record all distances and angle measured.

Results and Conclusions

1. Calculate your height by each of the methods indicated below. Be sure to indicate the equation used.

   a) Use the angle and the length of the string.
   b) Use the angle and the distance along the floor.
   c) Calculate the angle using the distance along the floor and the length of the string. Now calculate height from computed angle and distance along floor.
d) Use the Pythagorean theorem.

2. Calculate the percentage error for each calculated height value with the height measured from the direct measure.

3. List some applications in the indirect method of measuring height.

4. What are some possible sources of error in the indirect method of measurement?
Measurement and Accuracy

Materials:

- 50ml graduated cylinder
- ruler
- thermometer
- balance
- metal shot

Procedure:

**Deductive:** Determine the volume of a cylinder. Determine the mass and density of water. Determine the density of metal shot.

**Inductive:**

1. Measure the inside diameter of cylinder. Measure the height of the cylinder.
2. Determine mass of cylinder using balance.
3. Determine temperature of a beaker of water.
4. Fill cylinder to some value between 40 and 50 ml with water. Determine volume and mass.
5. Pour out some water until volume is between 25 and 30 ml. Add some metal shot. Determine new volume and mass.

Data

Record all measurements made.

Results and Conclusions

1. Calculate volume of cylinder mathematically. Calculate percentage error of volume cylinder is calculated to measure with volume marked on it.

2. Calculate density of water from measurements. Calculate percentage error for water density by comparing calculated density with density of water at measured temperature.

3. Calculate density of metal shot using measurements recorded. Calculate percentage error of density by comparing calculated value with known value.

4. Account for any discrepancies between measured quantities and known values.
S.P.S. #2

Movement

Materials

track (175 cm board)
bright (metal)
stopwatch
ring stand
ring

Procedure

Deductive: Determine the average speed of a ball rolling 25, 50, 75, 100, 125, 150, and 175 cm. Determine the ball's acceleration and the effect the angle of the incline has on the acceleration.

Inductive:

1. Using the ring stand and ring, set up an incline with the track.

2. Using tape, mark off 25, 50, 75, 100, 125, 150, and 175 cm on the track.

3. Place the ball at the 25 cm mark. Hold it at the mark with a pencil. Release it and record time to travel 25 cm. Repeat for a total of 3 trials.

4. Repeat step #3 for each of the distances marked on the track.

5. Increase the incline of the track and gather data for the distances marked on the track as before.

Data

1. Make a table recording the time for each trial of each distance on the track. Also include a column for the average time for each distance.

2. In the table mentioned above, add a column for the speed of the ball in each distance.

3. Make a second table recording the data collected when the incline was increased. Add an additional column for the final velocity.
Results and Conclusions

1. Show one sample calculation for the average time.

2. Make a graph of distance on the incline versus average time. Place time on the horizontal axis.

3. Answer the following questions based on the distance-time graph.
   a) What is the shape of the line on your graph?
   b) How does the distance change as the time increases?
   c) According to the graph, what was happening to the ball on the track?

4. Show one sample calculation for the average speed of the ball for each distance trial.

5. Make a graph of speed versus time. Place the time on the horizontal axis.

6. Answer the following questions based on the speed-time graph.
   a) What would be the speed of the ball if the time we allowed for the ball to move was 0 seconds?
   b) Is the point (0,0) a point on the line?
   c) What is the shape of the line on your graph?

7. A moving ball is slowing down. Explain why it has acceleration.

8. How would increasing the incline of the track affect the acceleration of the ball?

9. Make a distance-time graph and a speed-time graph based on the data for the increased incline.

10. How did the acceleration of the ball on the second incline compare with the acceleration of the ball on the first incline?

11. How did the slope of the speed-time graph for the second incline compare with the slope for the speed-time graph of the first incline?
12. What is the relationship between the slope of the line of the graph of speed versus time and the acceleration?

13. Show one sample calculation for the final velocity in the second table.
S.P.S. #2

Kinematics of a Student

Materials

tape measure
stopwatches or watches with second hands

Procedure

Inductive:

1. Mark off a 30 to 40 meter course on the school football field. (See attached diagram.)

2. Line up pairs up students along the 40 meter course. Each of these students needs a stopwatch.

3. Have each student, one at a time, try to go (walking or running) through the course at a constant speed. Have the students start a few before the first timing station so they have a chance to get up to speed.

4. To take a set of data, the teacher blows a whistle to start all stopwatches and the student begins moving.

5. Each pair of timing students look at each other and when the moving student breaks their line of sight, they stop their watches.

6. Each timing station has a separate sheet to record names and times.

Data

1. Each student makes a table showing their time at each timing station and its distance from the starting point.

Results and Conclusions

1. For each timing station, calculate the speed.

2. Plot speed versus time. Find the slope of the graph. What is this value known as?

3. Find the slope at several points and compare. What does this show?
S.P.S. # 2

How High Can You Throw A Ball?

Materials

ball
clock with a second hand

Procedure

Inductive:

1. Throw a ball vertically as hard as you can.

2. Measure the time that elapses between the time the ball leaves the hand and the time it returns.

3. Repeat for several trials.

Data

1. Make a table with the trials and the times recorded.

Results and Conclusions

1. Determine the time for the ball it fall from the highest point reached. Explain your reasoning.

2. Determine the distance fallen using $s = \frac{1}{2}at^2$.

3. Compare the distances for each of the trials.

4. What are the sources of error in making these calculations?
S.P.S. # 2

Acceleration Due to Gravity From Water Drops

Materials

pie plates
meter stick
clock with second hand
burets

Procedure

Inductive:

1. Place the pie plate on the floor. Support the plate on 3 or 4 pencils to hear each drop distinctly.

2. Set up a glass tube with a spigot (buret) so that drops of water from the valve will fall at least 1 meter to the plate.

3. Measure the actual distance from the spigot to the pie plate.

4. Adjust the valve carefully until one drop strikes the plate at the same instant the next drop from the valve begins to fall. (You should hear a drop as you see one fall.)

5. Measure the number of drops that fall in one minute. Repeat for a total of 3 trials.

Data

1. Record the distance a drop falls.

2. Make a table to record the number of drops per minute for each trial.

Results and Conclusions

1. Determine the average number of drops in one minute.

2. Determine the time for one drop.

3. Calculate the acceleration due to gravity for a drop.
4. Calculate the percent error for the acceleration due to gravity.

5. List some sources of error.

6. How would the formation of a puddle on the plate change your results?

7. How would decrease in water in the tube after a period of dripping affect the rate of dripping?
S.P.S. # 3

Distance and Displacement

Materials
- sharp pencil
- paper
- ruler
- protractor
- tape measure

Procedure

Inductive:
1. Walk down the hall of the school building. Measure the distance walked.
2. Turn into an adjacent hall that makes a sharp left or right turn. Walk down this hall and measure the distance.

Data
1. Record distances measured.

Results and Conclusions
1. Make a scale drawing showing the directions and distances walked.
2. Using the scale drawing, draw a vector diagram and measure the resultant vector.
3. Solve for the resultant vector algebraically.
4. Compute the total displacement.
5. Compare the displacement with the resultant.
Components of Force Vectors

Materials

- string: 2 50cm pieces & 1 10cm piece
- 500g hooked mass
- horizontal support or 2 rings stands
- 2 clamps
- meter stick
- protractor
- 20-N spring scales

Procedure

Deductive: Investigate the relationship between the angle of an applied force and the magnitude of one component.

Inductive:

1. Tie the 3 pieces of string together as shown in the figure.

2. Attach a 500g mass to the end of the short string and spring scales to the other 2 strings.

3. Hang the scales securely from a horizontal support so the 2 long strings form an angle of 15° where they meet. Adjust the strings until the scales read approximately the same.

4. Use the protractor to measure the exact angle between the strings. Record the angle and force (scale reading).

5. Move the strings farther apart and repeat step #4. Continue for 8 readings and are almost to the limit of the scales. Be sure to have some readings at angles greater than 120°.
Data

1. Make a table to record the angle and force measured at each.
2. Record the mass of the hanging weight.

Results and Conclusions

1. Calculate the weight of the hanging mass.
2. Draw a graph of force versus the angle.
3. How does changing the angle affect the force on each string?
4. For what angle of the string were the forces on the strings the least? The greatest?
5. For what angle of the string was the force on the strings the same as the suspended weight?
6. Explain how the arithmetic sum of the 2 forces can be greater than the load.
7. Give 1 practical application of this study.
S.P.S. # 3

Coefficient of Friction

Materials
- spring scale
- level board
- wooden block
- protractor

Procedure

Deductive: Determine the value of the coefficient of sliding friction using an inclined plane.

Inductive:
1. Place a wooden block inclined so that the block does not move.
2. While gently tapping the board, lift the plane until the block slides down the board at a constant velocity.
3. Measure the angle of the plane with the horizontal and record.
4. Measure the weight of the block.

Data
1. Record the angle of the plane.
2. Record the weight of the block.

Results and Conclusions
1. Draw a diagram showing the incline, the angle of the incline, the block, and the direction the weight of the block acts. Add to the diagram the direction of the parallel force and the perpendicular force on the block.
2. Calculate the value for the parallel and perpendicular forces.
3. Calculate the value of the coefficient of friction.
4. Show that \( u = \tan \) of the angle of incline.
5. Calculate the percentage error for the calculate \( u \) in step #3 with the \( u \) in step #4.
S.P.S. #4

The Laws of Motion

Materials

- spring carts
- metersticks
- weights
- stopwatches

Procedure

Deductive: Compare the change in velocities of 2 carts of equal mass starting from rest with 2 carts, one twice the mass of the other, starting from rest.

Inductive:

1. Determine the mass of 2 spring-loaded carts. Add weights to them if necessary to equalize masses.

2. Position carts, with cylinders pushed into the carts, with the front faces of the carts touching each other.

3. Release the spring on one of the carts while measuring the time necessary for each of the carts to come to rest. Also measure the distance traveled by each cart. Repeat for a total of 3 trials.

4. Repeat the procedure in step #3 but add weights to one of the carts so it is double in mass to the other cart.

Data

1. Make a table to record the masses of the 2 carts, their distances and times for the 3 trials when their masses are equal. Add a column to record the change in velocity for each cart's trial.

2. Make a table similar to the one described above for when the masses of the 2 carts are different.
Results and Conclusions

1. Show one sample calculation for the change in velocity of each cart's trial.

2. How did the change in velocities of the equal mass carts compare?

3. How did the change in velocities of the unequal mass carts compare?

4. What explanation would you give for the differences in your answers to questions 2 and 3?

5. Using the data in both tables, what mathematical equality could you write to explain the data you obtained from your work with the equal mass carts and the unequal mass carts?

6. What name would you give the product of mass and change in velocity?

7. State the Law of Conservation of Momentum. How was momentum conserved in your investigation?

8. Rewrite Newton's Second Law of Motion (F=ma) in terms of the variables F, v, m, and t.

9. How can you apply this new equation to the Old Table Cloth trick?
How Does Your Weight Change? - Take Home Lab

Materials
bathroom scale

Procedure

Inductive:

1. Stand on a bathroom scale and note its reading.

2. Now, let your body be accelerated downward by doing a single rapid knee bend. Record scale reading.

3. Now, from the squat position, come up quickly to the erect position. Record scale reading at the moment you accelerate upward.

Data

1. Record scale readings and when made.

Results and Conclusions

1. What happens to the scale reading when you are descending? Why?

2. What happens to the scale reading when you are ascending? Why?

3. List some possible sources of error.
S.P.S. #5

Circular Motion

Materials

10 cm glass tube
string or cord (1.5 m)
size 4 stopper, 2-hole
25 iron washers
stopwatch
alligator clip

Procedure

Deductive: Determine the relationship between
the centripetal force, the velocity of an object
moving in a circular path, and the radius of
the path.

Inductive:

1. Tie the rubber stopper to one end of the cord.
Pass the free end of the cord through the
glass tube and attach the paper clip to that
end. Bend the paper clip so that it will
support the metal washers.

2. Hang 5 washers at the end of the cord.
Adjust the cord so that the radius of the
circular path of the stopper will be about
80 cm to the middle of the stopper. Mark
this by attaching an alligator clip at this
point.

3. Practice whirling the stopper in a horizontal
circular path above your head. Move the tube
as little as possible. The stopper is traveling
the desired speed when the alligator clip
is positioned just below the tube.

4. When the stopper is moving at the correct
speed, have a partner measure the time it
takes the stopper to complete 30 revolutions.

5. Add 5 more washers and repeat step #3.

6. Repeat steps #4 and #5 adding 5 washers at a
time until a total of 25 washers is added.

Data

1. Make a chart of the number of washers versus
the time for 30 revolutions.
2. Make a second chart for the time for 1 revolution, the speed of the stopper, and the speed squared.

3. Record the radius of the circle and the circumference.

**Results and Conclusions**

1. Calculate the time for 1 revolution for each trial.

2. Calculate the circumference of the circular path.

3. Determine the speed of the stopper for each trial using the circumference.

4. Determine the speed squared for each trial.

5. Plot the force (number of washers) on the vertical axis and speed on the horizontal.

6. What does the shape of the curve reveal about the relationship of the 2 variables?

7. Plot force on the vertical axis and the speed squared on the horizontal.

8. What does the shape of the curve in #7 show?

9. Do the results of your investigation support the equation in your text for centripetal force?
S.P.S. #5

Centripetal Force

Materials

fire polished glass tubing
string
tape
nickels
clock with second hand

Procedure

Inductive:

1. Pass a 1 meter piece of string through the glass tubing and fasten a nickel to one end of the string by means of a strip of tape.

2. Fasten a pile of nickels together with tape and attach this pile to the opposite end of the string.

3. Make an ink mark at a point on the string 30 cm from the center of the single nickel.

4. The single nickel will serve as a known mass of 5 g.

5. The pile of nickels will be the body whose weight is to be measured.

6. Hold the glass tubing vertically and swing the single nickel over your head in a horizontal circle. Allow the radius of the circle to increase until it is at the 30-cm mark and adjust the speed of rotation until the weight of the 10 nickels is supported by the force exerted on the string by the rotating nickel.

7. Count the number of complete turns made by the nickel in a 10 second interval. Repeat for a total of 3 trials.

Data

1. Make a chart with the number of turns versus time.
Results and Conclusions

1. Determine the average number of turns completed in the 10 second interval.

2. Determine the period of rotation.

3. The weight of the 10 nickels is the centripetal force that keeps the single nickel moving in a circle. Compute the centripetal force.

4. Assuming the mass of each nickel is 5 g, compute the weight of 10 nickels from the relationship $W=mg$.

5. Compare the weight of the 10 nickels with the calculated centripetal force.

6. What are some of the sources of error in this method of determining the weight of an object?
S.P.S. # 6

Velocity of a Softball

Materials

- cardboard box
- packing material
- softball
- meter stick
- spring scale
- platform balance

Procedure

**Deductive:** Determine the velocity of a softball using the law of conservation of momentum.

**Inductive:**

1. Pack a cardboard box loosely with packing material so that a softball thrown into box will remain there.
2. Measure and record the mass of the box and the packing material.
3. Place the box on a smooth surface and mark the position.
4. Throw the ball into the box.
5. Measure and record the distance the box and ball moved.
6. Measure the force of friction by pulling the box and ball over the surface with a constant velocity. Record.
7. Measure and record the mass of the box, packing and ball.

Data

1. Make a table recording all measurements made.

Results and Conclusions

1. What is conserved in this lab? Write the equation for this relationship.
2. What causes the box to stop moving?

3. Calculate the acceleration of the box as it comes to rest.

4. Calculate the velocity of box-ball system after the collision, using the displacement and the acceleration.

5. Using the equation from question 1, calculate the initial velocity of the softball.
S.P.S. # 6

Momentum

Materials

2 spring carts
2 bricks
2 metersticks
wood and clamps to make bumpers

Procedure

Inductive:

1. Load each cart with a brick. Join 2 carts with springs compressed. Trip the spring and observe the carts' motion.

2. Set up wooden bumpers at the ends of a table. Place the carts in the middle of the table, release the spring, and listen for impact of each cart with a bumper.

3. Repeat step #2 with one cart having no brick and the other having 2 bricks.

Data

1. Record all observations.

Results and Conclusions

1. In step #2, do the carts seem to have the same velocity? The same momentum?

2. In step #3, do the carts have the same velocity? The same momentum?

3. What relationship seems to exist between the momentum of the brickless cart with the 2-brick cart?
The Pendulum

Materials
- pendulum support
- thread or string
- meterstick
- stopwatch
- small pendulum bobs (50 g & 100 g)

Procedure

**Deductive:** Determine the effect of bob mass, arc of swing, length of string, and the number of swings upon the period of a pendulum.

**Inductive:**

1. Suspend the 50 g and 100 g pendula side by side. Make each pendulum the same length.

2. Using a ruler, pull the bobs aside together to the same height so that they will swing through a short arc. Release the bobs simultaneously and determine the time for 40 swings.

3. Start the bobs simultaneously again, but this time release from a different height. Observe the bobs to see if they both arrive at the bottom of their swings together.

4. Start the bobs simultaneously and time for 20, 40 and 60 swings.

5. Remove one of the pendula. Vary the length by 10's beginning with 10 cm to a final length of 80 cm. For each length, determine the time for 40 swings.

Data

1. Make a chart for the 2 masses and 40 swings.

2. Make a chart for the 2 masses and different number of swings.

3. Make a chart of the different lengths and time.

4. Record observations from different heights.
Results and Conclusions

1. Does varying the mass affect the time for the swings?

2. Does varying the height from which the bobs are released affect the time for the swings?

3. Determine the period for each length tried. Determine the period squared for each.

4. Does varying the length of the pendulum affect the period?

5. Does varying the number of swings affect the period of the pendulum? Verify mathematically.

6. Plot the period on the vertical axis and the corresponding lengths on the horizontal axis. Describe the curve obtained.

7. What does the curve indicate about the relationship between the period of the pendulum and its length?

8. Plot the length of the pendulum on the horizontal axis and period squared on the vertical. Describe curve obtained.

9. What kind of a relationship between length and period squared is suggested from the graph?

10. Using the data for the 40 cm pendulum, calculate the acceleration due to gravity.

11. Determine the percent error for the calculated acceleration due to gravity with the actual value.
Prediction of Trajectories

Materials

- stopwatch
- ball or marble
- meterstick
- cup
- ramp

Procedure

Inductive:

1. Measure the time it takes a ball to roll a distance across a table top after rolling down a ramp. Catch the ball as it comes off the end of the table.

2. Repeat the measurement several times, always releasing the ball from the same place on the ramp, and take the average of the velocities.

3. Measure the vertical distance of the table and use it to calculate the horizontal distance the ball would travel if it wasn't caught.

4. Place a cup on the floor at your predicted landing spot and test your prediction.

Data

1. Record the distance the ball rolls along the table.

2. Record the time for the ball to roll.

3. Record the vertical distance to the table.

Results and Conclusions

1. Find the average of the velocities using $v = \frac{d}{t}$.

2. Find the time it takes to fall vertically.
3. Using the equation in result #1 and the equation in result #2, and substitute the value for time in equation #1 for time in equation #2. This can be used to calculate how far out from the edge of the table the ball will land.

4. How accurate was your prediction?

5. How could you determine the range of a ball launched horizontally by a slingshot?

6. Assume you can throw a baseball 40 meters on the earth's surface. How far could you throw the same ball on the surface of the moon, where the acceleration due to gravity is one-sixth what it is on the surface of the earth?
S.P.S. #7

How Fast Does the Water Flow? - Take Home Lab

Materials

- water hose
- meterstick or tape measure

Procedure

**Deductive:** Determine the velocity of the water flowing from the hose using horizontal and vertical distance measurements only.

**Inductive:**

1. With the hose nozzle held horizontally, measure its height above the ground.

2. Measure the horizontal distance the water travels before hitting the ground.

Data

1. Record all measurements made and label.

Results and Conclusions

1. Assuming that the time that the water remains in the air is the same as the time it takes the water to fall the vertical distance of the hose, calculate the time in the air using $s = \frac{1}{2}at^2$.

2. Now using the horizontal distance traveled and the time the water is in the air, calculate the velocity of the water.

3. List some possible sources of error.
How Fast Does A Softball Leave the Bat?

Materials

- softball & bat
- measuring tape
- watch with second hand

Procedure

**Deductive:** By measuring the horizontal distance a softball covers and the time it is in the air, calculate its velocity.

**Inductive:**

1. Each student gets a chance to hit the ball. The distance and time data are recorded.
2. Two or three students are also asked to throw the ball as far as possible.

Data

1. Students make a table recording the distance, time, horizontal velocity, vertical velocity, average velocity, and angle of ball. They will calculate only their own but include the other students' values.
2. Students will also make a table including the above categories for the thrown softballs.

Results and Conclusions

1. Students will calculate their horizontal speed using \( v_x = \frac{d}{t} \).
2. Students will calculate their vertical speed using \( v_y = \frac{1}{2}gt \).
3. Students will calculate their average speed using \( v = \left( \frac{v_x^2 + v_y^2}{2} \right)^{\frac{1}{2}} \).
4. Students will calculate the angle of their hit using \( \theta = \tan^{-1} \frac{v_y}{v_x} \).
S.P.S. # 8.

How Much Energy Does A Bouncing Ball Lose?

Materials

rubber ball
meterstick

Procedure

Deductive: Determine how much of its potential energy a rubber ball loses in making one bounce.

Inductive:

1. Drop a rubber ball from heights of 8, 7, 6, 5, 4, 3, and 2 feet from the floor.

2. In each case, measure the height to which the ball rises after each bounce.

Data

1. Make a table showing the original height and height to which the ball bounced.

Results and Conclusions

1. In each case, determine the ratio to which the ball returns with the height from which it was dropped.

2. If the ratio in #1 is equal to the ratio of the potential energy after bouncing to the potential energy before (mgh/mgh), make a graph showing how this fraction varies with the distance fallen by the ball.

3. What conclusions can you draw from your graph about the part of its energy the ball loses after a bounce?
S.P.S. #8

What's Your Horsepower?

Materials

   meterstick
   clock with second hand

Procedure

   Deductive: Determine the horsepower needed to walk and run up a flight of stairs.

   Inductive:

   1. Measure the height of one step.
   2. Record the total numbers of steps.
   3. Record the time to walk and run up the stairs.

Data

   1. Record all distances and times measured.

Results and Conclusions

   1. Determine the total distance walked.
   2. Determine the work to walk up the stairs.
   3. Determine the work to run up the stairs.
   4. How does the work in #2 and #3 compare?
   5. Determine the power you exerted when walking up the stairs.
   6. Determine the power you exerted when running up the stairs.
   7. Convert the power calculated in #5 and #6 to horsepower using 1 hp = 746 watts.
   8. Compare the horsepower in walking and running.
Gravitational Energy to Thermal Energy

Materials
- glass or plastic tube (1 m long & 2-3 cm in diameter)
- solid rubber stopper
- 1-hole stopper
- thermometer
- lead shot
- balance
- graduated cylinder

Procedure

Inductive:

1. Place the solid stopper in one end of the tube. Determine the mass of the metal shot and then pour it into the tube. Fill the tube with water. Insert a thermometer into the 1-hole stopper and place the stopper in the other end of the tube.

2. Record the temperature of the water.

3. Have a student turn the tube end-over-end 30 times. Make sure all the shot reaches to the bottom before the tube is turned again.

4. Pass the tube from student to student, each student carrying out step #3, until the whole class has contributed.

5. Record the final temperature and measure the volume of the water.

Data

1. Record all measurements made.

Results and Conclusions

1. Calculate the work done by the earth's gravitational field on the metal.

2. What temperature rise would you predict?

3. Calculate the percent error between the actual temperature rise and the calculated one.
How Efficient is Your Coffee Pot?

Materials

electric coffee maker
thermometer
clock

Procedure

Inductive:

1. Put a quart of cold water into the coffee maker and measure its temperature.

2. Turn on the heater and record the temperature of the water at 2 minute intervals until the water reaches a temperature of 90°C.

Data

1. Make a chart showing the time intervals and the temperature of the water at each.

Results and Conclusions

1. Assuming that one quart of water has a mass of 950 g, compute the number of calories absorbed by the water.

2. Express the heat absorbed in joules.

3. Determine the rate of heating in watts by dividing the energy in joules by the total time of heating in seconds.

4. Compare the wattage calculated with the wattage indicated on the coffee maker.

5. Plot the temperature of the water against the elapsed time.

6. Determine from your graph whether the heating takes place at a constant rate.
S.P.S. # 9

Specific Heat of a Metal and Water

Materials

2 identical beakers (1 liter)
hot plate or 2 identical lab burners
2 thermometers
piece of lead (about 0.5 kg)
balance

Procedure

Deductive: Determine the difference between heating a beaker of water with a beaker of water and lead. The masses being heated are identical.

Inductive:

1. Determine the mass of the lead and place it in one beaker with an equal mass of water.

2. Add water to the other beaker equal to the mass of water and lead in the first beaker.

3. Place the 2 beakers on the hot plate or over the 2 burners so that the beakers receive equal amount of heat.

4. Observe and record the change in temperature every 15 seconds.

Data

1. Record the masses measured.

2. Make a table recording the temperature changes for each beaker and the time.

Results and Conclusions

1. In which beaker does the temperature rise faster?

2. Which beaker has the lowest specific heat? Explain.

3. Which has the lower specific heat, lead or water? Explain.

4. Should a coolant have a high or low specific heat? Why?
The Specific Heat of a Metal

Materials
- calorimeter
- beaker to heat water in
- metal mass
- thermometer
- hot plate
- platform balance
- string

Procedure

Deductive: Using the law of conservation of energy, determine the specific heat of a metal.

Inductive:
1. Heat a half-full beaker of water to boiling.
2. Measure the mass of the calorimeter cup. Fill half full of cool water. Measure the mass of the cup and water. Measure the temperature of the water. Place in calorimeter jacket and cover it.
3. Measure the mass of metal used. Using string, lower the metal into the boiling water. Let metal remain in boiling water for 5 minutes. Measure the temperature of the boiling water.
4. Remove the metal from the boiling water and quickly lower it into the cool water. Replace the cover at once.
5. Stir gently with the thermometer. Record the constant temperature to which the water reaches.

Data
1. Record all measurements made.

Results and Conclusions
1. Determine the mass of the cool water used.
2. Determine the change in temperature of the metal.
3. Determine the change in temperature of the cool water and cup.

4. Calculate the thermal energy gained by the water and the cup.

5. Assuming that the heat gained equals the heat lost, determine the specific heat of the metal.

6. Calculate the percent error for the specific heat of the metal used.

7. Suggest possible sources of error.
The Bath Tub As A Ripple Tank? - Take Home Lab

Materials

- light source
- bath tub
- stick

Procedure

Inductive:

1. Fill a tub about 1 foot full of water.
2. Locate a strong concentrated light source about 5 feet above the tube.
3. Disturb the wave with the end of the stick and describe observations.
4. Vibrate the end of the stick vertically at a regular rate and describe observations.
5. Describe observations when the waves produced hit the flat side of the tub.
6. Lay a straight dowel, about a foot long, on the water and move it up and down at a regular rate. Describe observations.
7. Make circular waves in 2 different parts of the tube and note observations.
8. Estimate the speed of the waves by timing their motion over a fixed distance.

Data

1. Record all observations made.

Results and Conclusions

1. What do waves carry?
2. What are periodic waves?
3. What occurs when waves meet?
4. What type of waves are made in water? How do these differ from longitudinal waves?
S.P.S. # 10

Slinky Waves

Materials

Slinky
string or fishing line
smooth pole or stiff wire
curtain rings

Procedure

Inductive:

1. Cut equal-length pieces of string at least one meter long.

2. Tie a curtain ring to one end of each string.

3. Attach the free end of a piece of string to every fifth coil of the Slinky.

4. Slip the curtain rings onto the pole (or wire) and then suspend it from the ceiling.

5. Send a longitudinal pulse down the spring by pinching together several coils of the spring and then releasing them. Describe observations.

6. Quickly pull the free end of the Slinky to one side and then return it to its original position. Describe observations.

7. Determine the time it takes a pulse to travel down the spring. Change the amplitude of the pulse and again determine the travel time.

8. Change the medium by stretching the spring to a different length. Determine the speed of a pulse in this new medium.

9. Vary the amplitude and repeat step #8.

10. Tie a piece of string (1 m) to one end of the Slinky. With a student extending the string, send a pulse down the Slinky from the free end.

11. Repeat step #10 holding the end of the string securely.
12. Have 2 students send simultaneous pulses from opposite ends of the spring.

Data

1. Record all observations and measurements. Make sketches when necessary.

Results and Conclusions

1. What kind of pulse is generated in step #5? What happens to the shape of the pulse as it travels down the wire?

2. What kind of pulse is generated in step #6? What happens to the shape of the pulse as it travels down the string?

3. How does changing the amplitude affect the speed of the wave?

4. How does changing the medium affect the speed of the wave?

5. What happens when the pulse arrives at the boundary between 2 media?

6. How do the phases of the original and reflected pulses compare when the reflection is from a rigid barrier? a nonrigid barrier?

7. What happens when pulses from opposite ends of the spring meet?

8. What happens to the pulses after they have passed through one another?
Inverse Square Law

Materials

- point source of light
- square cardboard screen and supports
- small square of cardboard
- stick or pencil
- tape

Procedure

Deductive: Determine the relationship between the distance between a screen and light source to the area of shadow formed and the intensity of the light.

Inductive:

1. Mark off the large cardboard screen into 9 equal areas.

2. Cut a small piece of cardboard to the size of one of the areas above. Attach the stick to one side of the card with tape for a handle.

3. Support the screen erect with books or other supports.

4. Darken the room and turn on the light source. Position the small piece of cardboard very close to the screen about 10 cm from the light source. The shadow will cover one square of the screen.

5. Keep the distance between the card and light source constant. Move the screen away until the shadow covers 4 squares. Measure the distance from the light source to the screen.

6. Move the screen again until the shadow covers 9 squares. Measure the distance from the light to the screen.

Data

1. Record all measurements made.
Results and Conclusions

1. How does the area of the screen covered vary with the distance of the screen from the source?

2. How do you think the intensity of the light varies with the distance?

3. Make a graph of area covered versus distance from light source. What does the graph show?
S.P.S. # 11

How High Is A Flagpole?

Materials

meterstick

Procedure

Deductive: Determine the height of a flagpole indirectly.

Inductive:

1. Hold a meterstick vertically with one end resting on the ground.

2. Measure the length of the shadow of the stick cast by the sun.

3. Now, measure the length of the shadow of the flagpole.

Data

1. Record all measurements made.

Results and Conclusions

1. Determine the height of the flagpole using the ratio of the flagpole's height to its shadow equalling the ratio of the meterstick's height to its shadow.

2. List any possible sources of error.
Grease Spot Intensity

Materials

2 lamps with different watt bulbs
paper
meterstick or tape measure
butter or oil

Procedure

Inductive:

1. Place a circular grease spot in the middle of a piece of paper.

2. Arrange the 2 lamps about 12 feet apart and darken the room.

3. Move the paper, held vertically, between the 2 lamps until the grease spot seems to disappear.

4. Measure the distance from the paper to each lamp.

Data

1. Record the 2 distances measured.

Results and Conclusions

1. When the grease spot seems to disappear, the intensity of illumination cast by one lamp on its side of the paper is equal to the intensity of illumination cast by the second lamp on its side of the paper. Using the distances measured, calculate the ratio of the candle powers of the two lamps. \( \frac{I_1}{I_2} = \frac{d_1^2}{d_2^2} \)

2. List possible sources of error.
S.P.S. #11

Multiple Images From Plane Mirrors

Materials

2 plane mirrors
2 wood blocks
2 rubber bands
protractor
straightedge
paper

Procedure

Deductive: Determine the relationship between the number of images formed and the angle between 2 plane mirrors.

Inductive:

1. Attach a mirror to each of 2 blocks by placing a rubber band around the middle of the block and mirror.

2. Draw a line across the top of the paper, about 6 cm from the top edge. Place the mirrors along the line, side by side. The angle between the mirrors is 180°.

3. When you look directly at the mirrors, you see the images of the 2 rubber bands (images).

4. Mark the center point. Hold one mirror firmly in place. Always keeping the front interior sides of the mirrors in contact, start rotating the second mirror to decrease the angle between the mirrors.

5. Make all observations from directly between the mirrors, looking at the center point.

6. Slowly rotate the mirror until you first see 4 images. Mark the position of the mirror.

7. Continue rotating the mirror, and mark the positions where you first see 6, 8, 10, and 12 images. (Look along the center line!)

8. Remove the mirrors, and draw rays from the mirror positions to the center point. Measure and record the angles.
Data

1. Make a table recording the number of images, the angle at which they were observed, and one less than the number of images formed.

Results and Conclusions

1. Plot the number of images minus one versus the angle between the images.

2. What kind of relationship does the graph show?

3. What is the general equation for this type of graph?

4. Using the figures in your data table, determine a value for the proportionality constant for the equation in #3 and write a specific mathematical statement relating angle and the number of images minus one (n-1).
S.P.S. # 11

Law of Reflection

Materials

- plane mirror
- straight pins
- ruler
- rubber band
- paper
- wood block
- protractor
- cardboard

Procedure

Inductive:

1. Place paper on cardboard. Draw a line across the middle of the paper (short way). Support the mirror vertically using the block and the rubber band. Center the mirror along the line.

2. About 4 cm in front of the mirror center, make a dot on the paper. Place a pin upright in the dot.

3. Place your ruler about 5 cm to the left of the pin. Sight along the edge of the ruler until the image of the pin in the mirror is aligned. Draw a line along the ruler.

4. Repeat, placing the ruler 3-4 cm to the left of original position.

5. Set up the mirror again on another sheet of paper with a line across the middle. Draw a triangle in front of the mirror and label the vertices.

6. Place a pin in vertex A. Sight along the ruler to obtain 2 lines from the image of the pin at A.

7. Repeat the process with the pin at the other 2 vertices.

Data

1. Make all lines and measurements on paper that are mentioned in the procedure and results.
2. Make a table for all measurements for drawing #1.

3. Make a table for all measurements for the triangle drawing.

Results and Conclusions

1. Extend the 2 lines on drawing #1 to the mirror line. Using dotted lines, extend these 2 lines behind the mirror line until they intersect. This is the position of the image. Label.

2. Measure the perpendicular distance from the object to the mirror line and from the image to the mirror line. Compare.

3. To show the law of reflection, draw a line from the pin point (object) to the mirror line such that this line intersects first ruler line at the mirror line. Draw a normal between these 2 lines. Measure the 2 angles and record.

4. Repeat step #3, intersecting the line from the object point with the second ruler line. Draw a normal and measure the angles.

5. How does the object distance compare with the image distance?

6. How does the angle of incidence compare with the angle of reflection for each ruler line?

7. Repeat basic steps above for the ruler lines of the triangle until an image triangle is formed. Measure the perpendicular distances from each vertex (object and image) to the mirror line and compare.

8. Summarize the general characteristics of the image formed by a plane mirror.
Snell's Law

Materials

rectangular glass plate or plastic
protractor
ruler
paper

Procedure

Inductive:

1. Place the glass plate in the center of a sheet of white paper. Trace its outline.

2. Remove the glass plate and construct a normal at the top left of the outline.

3. Using your ruler and protractor, draw a heavy line at an angle 30° to the left of the normal. Label AB.

4. Replace the glass plate over the outline. With your eyes on a level with the glass plate, sight along the edge of the glass plate opposite the line AB until you locate the line through the glass. Sight your ruler along this line until its edge appears to be a continuation of the line. Draw a line along the ruler. Label CD.

5. Repeat the above steps using a 45° angle.

Data

1. Make a chart for the angle of incidence, angle of refraction, the sine of each angle, and the index of refraction of each.

2. Label all lines drawn either in procedure or results on drawing.

Results and Conclusions

1. On each drawing, connect line AB with CD.
2. On each drawing, draw a normal along the bottom of the rectangle for line CD.

3. Measure the angle between line CD and the normal on each drawing. This is the angle of refraction.

4. Record the sines for each angle of incidence and each angle of refraction.

5. Calculate the index of refraction for each drawing.

6. How well do the 2 values for the index of refraction compare with the actual value?

7. Calculate the percent error for the 2 index of refraction values with the accepted value.
S.P.S. #11

Curved Mirrors

Materials

- concave mirror
- meter sticks
- index card
- candle
- holders for meter stick and mirror

Procedure

Deductive: Observe the position and characteristics of images produced by concave mirrors.

Inductive:

1. Place the mirror in a holder on a meter stick. Hold a candle at a great distance (10 m or more) from the mirror. Locate a sharp image on the index card. Measure the distance from the card to the mirror. Record this as the focal length of the mirror.

2. Locate the candle at the following distances from the mirror and record the type of image formed, size of the image, location of the image, and direction of the image: 4f, 3f, 2f, f, and \( \frac{1}{2}f \).

Data

1. Make a table recording all measurements and observations made.

2. Record the focal length of the mirror.

Results and Conclusions

1. At what locations of the object is the image real, virtual, larger, smaller, the same size, inverted, and erect?

2. Plot the location of the object versus the location of the image. What does the graph show about their relationship?
S.P.S. #11

Convex Lenses

Materials

double convex lens
meter stick
index card
candle
meter stick and lens holders

Procedure

Deductive: Observe the position and characteristics of the images produced by convex lenses.

Inductive:

1. To locate the focal length of the lens, follow the same procedure used to locate the focal length of the concave mirror.

2. Locate the object at the following distances from the lens and record the image position, size, direction, and type: 4f, 3f, 2f, f and $\frac{1}{2}f$.

Data

1. Make a chart showing the image characteristics at each object location.

2. Record the focal length of the lens.

Results and Conclusions

1. When is the image real?

2. When is the image virtual?

3. Describe how the image size changes as the object nears the lens.

4. When is the image erect?

5. Plot object distance versus image distance. What relationship does the graph indicate?
S.P.S. #11

Polarization of Light

Materials

- pair of polarizing lenses from sunglasses
- cellophane & other transparent objects
- piece of thick clear plastic
- text or magazine with shiny cover

Procedure

Deductive: Investigate some of the characteristics of polarized light.

Inductive:

1. Look through the 2 filters at a light source. Hold one filter (the polarizer) steady while rotating the other filter (the analyzer). Rotate the analyzer through several complete turns. At the point where the transmitted light is at a minimum, the filters are said to be crossed. Describe observations.

2. Hold magazine with shiny cover so that light shining on it makes a glare. Look at the surface through one filter as you rotate the other. Look at other reflective objects. Describe observations.

3. Fold a piece of cellophane so that the thickness varies. Have your partner hold the 2 filters in the crossed position while you rotate the folded cellophane between them. Describe observations.

4. Insert a piece of thick clear plastic between the crossed filters and bend it. (A clear plastic cellophane tape holder works well.) Describe observations.

5. Take a polarizing filter outside and observe light from many sources such as car bodies. Describe observations.

Data

1. Make a chart describing observations from each activity described above.
Results and Conclusions

1. How far did you have to rotate the analyzer for the transmitted light to go from maximum to minimum?

2. Why are polarizers said to be crossed when the transmitted light is at a minimum?

3. What did your observations in procedure step 2 tell you about reflected light?

4. How do ordinary sunglasses work? How are polarizing sunglasses different?
S.P.S. # 11

**Diffraction Patterns**- Take Home Lab

**Materials**

- thin handkerchief
- screening
- single-edged razor blade
- needle
- 2 combs
- color filters or colored cellophane
- old photographic negatives
- light bulb

**Procedure**

**Inductive:**

1. Look at a distant light source, such as a streetlight or a strong lamp across the room, in the following ways and describe/sketch observations: through a handkerchief; through some screening; through 2 combs held against each other (one with the teeth up, one with the teeth down) moving the combs back and forth; along the edge of a piece of paper, a sharp knife, or a razor blade; and through the eye of a needle.

2. Cut a narrow slit in a piece of exposed film or a piece of paper with a single-edged razor blade. Describe what you observe when you slowly pull the slit apart.

3. Use the film from step #2 and observe the light when you place different-colored filters in front of the light. Describe what you see.

**Data**

1. Record sketches and observations made.

**Results and Conclusions**

1. Define diffraction.

2. Distinguish between the patterns observed when using white light and colored light.

3. Was there a difference in the width of the bands observed with red and blue light if the slit width is constant? Explain.
S.P.S. # 12

**Electrostatics**

**Materials**

- comb
- plastic rulers
- glass & rubber rods
- cloth, silk, fur
- cellophane tape

**Procedure**

**Inductive:**

1. Try rubbing a plastic comb or ruler with a piece of cloth or your hair. Then try picking up small pieces of paper with it. Describe.

2. Stick a 20 cm length of transparent tape to a table top. Press the tape down well, leaving 3 cm loose as a handle. Remove tape and test whether the non-sticky side will pick up a scrap of paper.

3. Charge a piece of tape as in step #2 and suspend it from the edge of the table. Now charge a second strip in the same way and bring it close to the first one. Describe.

4. Rub various plastic, rubber, and glass objects and test to see if they attract small pieces of paper.

**Data**

1. Record all observations made in the procedure.

**Results and Conclusions**

1. Is the paper in step #1 charged? Explain results.

2. Is the paper or the tape charged in step #2? Explain results.

3. Was there a force between the 2 tapes in step #3? Was it attractive or repulsive? Why?
S.P.S. # 13

Ohm's Law

Materials

- small light bulb and holder
- lead wires with alligator clips
- long wood lead (graphite) pencil
- 6 volt battery
- alligator clips

Procedure

Inductive:

1. Cut the top half of the wood away along the whole length of the pencil to expose the entire graphite column.

2. Wire the circuit as shown in the diagram. Connect one lead to one end of the graphite column.

3. Close the switch. Starting from the free end of the graphite column, slowly slide the clip attached to the second lead up the column until the 2 clips touch. Describe.

Data

1. Record all observations made.

Results and Conclusions

1. When is the light brightest?

2. Which is a better conductor of electricity, copper wire or graphite?

3. State Ohm's Law.
Water-Heating Efficiency of An Electric Heater

Materials
- electric heater for coffee or tea
- thermometer
- clock

Procedure

Inductive:
1. Put a liter of water into the heater and record its temperature.
2. Now heat the water and measure the time it takes to raise the temperature to 90°C.

Data
1. Record measurements made.

Results and Conclusions
1. Compute the heat in calories gained by the water.
2. Compute the electrical energy in joules supplied to the heater by multiplying the wattage rating shown on the heater by the number of seconds it was in operation.
3. Convert the electrical energy calculated to calories.
4. Calculate the efficiency of the heater using the ratio of the heat gained by the water to the electrical energy furnished to the heater.
S.P.S. # 13

Heating Effects of Electricity

Materials

nichrome wire
thin copper wire
alligator clips
copper leads
switch
6-V battery
wood block
paper

Procedure

Inductive:

1. Fasten alligator clips to 2 opposite sides of the wood block.
2. Wire the circuit as shown in diagram.
3. Close the switch and observe wire.
4. Touch a piece of paper to wire.
5. Open the switch and replace the nichrome wire with the thin copper wire. Close the switch.

Data

1. Record observations made.

Results and Conclusions

1. What energy transformations take place in this experiment?

2. Why did the copper wire and the nichrome wire behave differently?

3. What in your home operates like the nichrome wire?
S.P.S. # 13

**Series and Parallel Circuits**

**Materials**

- battery
- 3 light bulbs and holders
- wire with alligator clips
- ammeter
- voltmeter
- switch

**Procedure**

**Deductive:** Compare the current and resistance of 3 light bulbs connected in series and parallel.

**Inductive:**

1. Connect 3 bulbs in series with an ammeter, switch, and battery. Connect the voltmeter before the first bulb and to the last bulb.

2. Close the switch and record the ammeter and voltmeter readings.

3. Connect the 3 bulbs in parallel, then attach them to a circuit with an ammeter, voltmeter, switch, and battery. Close the switch and record the ammeter and voltmeter readings.

**Data**

1. Record all meter readings.

**Results and Conclusions**

1. Calculate the total resistance of the series circuit.

2. Calculate the total resistance of the parallel circuit.

3. How do the total resistances compare?

4. Assuming the resistance of each bulb is the same, what is the resistance of one bulb?
Coulomb's Law

Materials

2 pith balls coated with graphite
ring stand
clothespin
graph paper & support
thread
wood dowel
150-watt incandescent bulb
rubber rod & cat's fur

Procedure

Deductive: Test the relationship between the force between 2 charged objects and the distance between them.

Inductive:

1. Arrange apparatus as shown in drawing.

2. Mark the rest position of one edge of the shadow of hanging ball on the graph paper.

3. Charge the rubber rod. Touch it to the suspended ball and then to one mounted on the clothespin. They now are charged alike.

4. Move the mounted pith ball close to the suspended ball until a small deflection is obtained on the screen.

5. Make all measurements from the same edges on the 2 shadows. Measure d, the distance from the shadow of the suspended ball, when it is at rest to the shadow of the same ball when it is deflected. Measure R, the distance between the shadow of the mounted ball and the shadow of the deflected ball.

6. Move the mounted pith ball a centimeter or so closer and repeat measurements. Repeat for a series of 5 measurements.

Data

1. Make a chart for R and d. Also one for d$^2$ and the inverse of d$^2$. 
Results and Conclusions

1. Plot the force (in terms of $d$) versus the separation squared ($R^2$). What is the shape of the curve? What kind of relationship is indicated by this shape?

2. Plot the force versus the inverse of $d^2$. What type of curve is shown? What kind of relationship is indicated?

3. Suggest some possible sources of error.
S.P.S. # 15

Magnetism

Materials

bar magnet (2)
iron filings
washers
paper clips
nails
compass
current-bearing wire

Procedure

Inductive:

1. Lay a piece of paper on top of a bar magnet. Sprinkle iron filings on the paper and observe.

2. Lay a piece of paper on top of 2 bar magnets that are lying with like poles facing. Sprinkle with iron filings and observe.

3. Repeat step #2 with unlike poles facing.

4. Repeat step #3 with a washer between the magnets.

5. Record observations of a nail touching paper clips. Stroke the nail on the magnet and repeat.

6. Draw a diagram showing the position of the needle as a compass is slowly moved around a bar magnet.

7. Run a current-bearing wire through a piece of paper or index card. Hold the card horizontally and shake iron filings on it. Observe.

8. Wind the current-bearing wire around the nail and repeat step #5. Double the number of turns around the nail and repeat.

Data

1. Record observations and make sketches to record experiments performed above.
Results and Conclusions

1. Explain why a bar magnet is called a permanent magnet.

2. Explain why an electromagnet is called a temporary magnet. What acted as an electromagnet in your experiment?

3. What 3 factors determine the strength of an electromagnet?

4. Near what points is the magnetic field about a magnet most concentrated?
S.P.S. # 15

A Mass Spectrograph Model

Materials

- rectangular sturdy box (30 cm x 50 cm)
- steel balls of various masses
- strong bar magnet
- ruler or wedge of wood with groove down the center
- carbon paper
- large sheet of white paper to fit box

Procedure

Inductive:

1. Set up a launching ramp for the steel balls as shown in the diagram.
2. Place carbon paper under the white paper in the bottom of the box.
3. Roll a ball down the ramp to make sure it does in a straight line.
4. Place the bar magnet at the center of one side of the box.
5. Arrange the steel balls according to mass. Roll the balls down the ramp, one at a time.
6. After each roll, remove the carbon paper and mark the track of the ball with the relative mass of the ball making it.

Data

1. Make a sketch of the tracks on the white paper and identify each track with the relative mass of the ball that made it.

Results and Conclusions

1. Which ball was deflected the most? least? Why?
2. What do each of the following objects represent in an actual mass spectrograph? steel balls, magnet, ramp
3. List several uses of a mass spectrograph.
Diagram for Mass Spectrograph Model

Ramp

magnet
S.P.S. #19

Nature of the Atomic Nucleus

Materials

marbles
cylindrical glass tumbler
various shaped objects

Procedure

Inductive:

1. Place the glass tumbler on a sheet of paper and draw a line around the tumbler's position.

2. Roll marbles, one at a time, toward the target along a series of parallel lines. (Roll down the groove of a ruler.)

3. Record the direction of each marble before and after the collision on the paper. The pattern formed reveals the width and shape of the object.

4. Repeat the above procedure with a rectangular block and other objects as targets.

Data

1. Attach sheets showing the marble directions for each shaped object used.

Results and Conclusions

1. Compare your experiment to firing projectiles at an atomic nucleus.

2. How accurate are the results of this type of experiment for determining the width and shape of an object?
S.P.S. #19

Probability Waves

Materials

coins

Procedure

Inductive:

1. Toss a coin and let it fall to the floor. Record whether it lands heads up.

2. Repeat step #1 for a total of 30 times and keep count of the number of times it turns up heads.

3. Repeat the experiment by tossing the coin 50 times and 150 times.

4. Repeat the above experiments tossing 2 coins simultaneously.

5. Toss a pair of coins 40 times and count the number of times the result is 2 heads, 2 tails, and 1 head and 1 tail. Repeat the experiment by making 80 and 160 tosses.

Data

1. Make charts indicating the number of coins tossed, the number of times tossed, and the results of the tossing.

Results and Conclusions

1. The "probability wave" for coins predicts that for a given number of coin tossing, the number of heads will be half the number of tossing. How did your results compare with the probability waves for 30, 50, and 150?

2. The probability wave predicts that for 2 coins tossed, the results should be $\frac{1}{4}$ of them will come up 1 head and 1 tail, $\frac{1}{4}$ of them will come up 2 heads, and $\frac{1}{2}$ of them will come up 2 tails. Compare your results for 40, 80, and 160 with the predicted results.

3. What is the effect of increasing the number of tosses on the difference between the observed distribution and the predicted distribution?
S.P.S. 20

Speed of Sound Waves in Air

Materials

- tuning forks
- glass tube (50 cm long)
- large glass cylinder
- meterstick

Procedure

Inductive:

1. Fill the glass cylinder 3/4 full of water. Hold the glass tube in the cylinder with one of its ends in the water.

2. Strike the tuning fork with a rubber hammer. Hold the vibrating fork horizontally as close to the open end of the tube as you can. Move the tube and fork up and down until the sound is best reinforced.

3. Hold the tube in the position of best sound reinforcement. Measure the distance from the top of the glass tube to the water in centimeters.

4. Measure the diameter of the tube in centimeters.

5. Repeat for at least 1 other frequency of tuning fork.

Data

1. Make a chart that records the frequency of the fork, the length of the air column, the diameter of the tube, the corrected length of the air column, the wavelength, and the speed of sound.

Results and Conclusions

1. For each trial, find the corrected length of the air column by adding 0.4d (d=diameter) to length measured.

2. Calculate wavelength by multiplying 4 times corrected length.

3. Calculate velocity of sound.

4. Measure temperature of room and calculate velocity of sound. Calculate percent error.
Chapter 5

EVALUATIONS AND CONCLUSIONS

The laboratory curriculum format was evaluated by nine colleagues using an evaluation form (see Appendix B). The nine teachers evaluating the curriculum were all secondary science teachers who teach both biological and physical science courses. The reason for using all of the science teachers was the difficulty in having only Physics teachers, whose numbers are limited, to evaluate the curriculum for the Physics I course.

In general, all of the teachers surveyed liked the format used for the laboratory activities. They felt labeling each activity with the student performance standard number (S.P.S. #) was useful for teachers using the curriculum but not for the students.

The teachers surveyed appreciated the fact that most of the laboratory activities offered a choice of procedure, though most felt the procedure would be too difficult for the lower phase courses. They also appreciated being able to select the activities they preferred to use for each standard and that the materials needed for each activity were listed on the activity.
The teachers surveyed felt the organization of the laboratory curriculum, numerically by the state student performance standard numbers, was beneficial and that the development of similar curricula for all of the secondary science courses offered in Florida would be useful. They also commented favorably on the short and concise format of the laboratory activities.

Overall, the teachers' reactions were favorable to the laboratory curriculum. Minor format changes were mentioned by several of the teachers but this is an indication of how teaching styles differ. All nine teachers surveyed agreed that any assistance in correlating classroom activities with the State-mandated student performance standards are beneficial to classroom teachers as this laboratory curriculum developed provides.
REFERENCES


Florida Association of Supervision and Curriculum Development. (1983). The Impact of Increasing Requirements in Math and Science (Educational Leadership, 41, pp. 36-41)


APPENDIX A

State Performance Standards
After successfully completing this course, the student will be able to:

1. Use the scientific method to solve problems, employ metric measurements and demonstrate safe and effective use of laboratory instruments.

   The student will:
   1.01 represent scientific principles using mathematical format.
   1.02 construct one or more inferences or hypotheses from the information given in a table of data, graphs or pictures.
   1.03 name coordinates of points in three-dimensional graphs.
   1.04 construct a three-dimensional graph given number of triples.
   1.05 describe certain kinds of data using the mean, median and mode; construct predictions, inferences or hypotheses from this information.
   1.06 identify variables which are manipulated, responded to or held constant in an investigation or an experiment.
   1.07 design, conduct and report an experiment involving all the science processes where appropriate.
   1.08 apply appropriate questions when a problem is stated.
   1.09 collect, group, analyze, regroup and synthesize information to solve a problem.
   1.10 use a model or drawing to visualize the solution to a problem.
   1.11 employ safe laboratory procedures.
   1.12 choose science equipment appropriate for tasks.
   1.13 associate the names and functions of science equipment.
   1.14 recognize the current limitations of science (social problems, science is not equivalent to history, etc.).
   1.15 recognize the tentativeness of science "truth."

2. Solve kinematic equations.

   The student will:
   2.01 calculate average speed, instantaneous speed and change in speed given appropriate distance and time data.
   2.02 represent linear motion by use of speed/time, distance/time, and acceleration/time graphs.
   2.03 determine the instantaneous speed or acceleration by the slope method from appropriate time graphs.

3. Use vectors in solving problems.

   The student will:
   3.01 resolve a vector diagram into its x and y components.
   3.02 determine the resultant of two component vector diagrams.
   3.03 define a vector quantity as one which requires both a magnitude and a direction measurement.
   3.04 identify velocity and displacement as vector quantities.
   3.05 resolve a velocity vector into its horizontal and vertical components using trigonometric functions.

** Standards of Excellence
COURSE STUDENT PERFORMANCE STANDARDS


The student will
4.01 solve problems which require the use of Newton's Laws of Motion.
4.02 determine the mass of an object by using an inertial balance.
4.03 calculate the gravitational force between two objects given their mass and the distance between their centers.**
4.04 identify and define in an operational setting the three Newtonian Laws of Motion.**

5. Calculate uniform circular motion problems.

The student will
5.01 explain motion relationships involved in circular motion.**
5.02 calculate the magnitudes of velocity, force and acceleration vectors in uniform circular motion based on laboratory data.
5.03 given the mass, speed and orbital radius on an object traveling in uniform circular motion, determine the central force.

6. Apply conservation of momentum.

The student will
6.01 demonstrate mathematically the conservation of momentum in a one-dimensional collision.
6.02 calculate the rate of change of momentum when a specific force is applied constantly to a moveable object (neglecting friction).

7. Describe simple harmonic and projectile motion.

The student will
7.01 describe a projectile's motion in terms of its vertical and horizontal components.
7.02 quantitatively state the relationship between the restoring force and the displacement on an object moving in simple harmonic motion.
7.03 quantitatively compare the change in the period of an object moving in simple harmonic motion with given changes in maximum displacement or acceleration.

8. Apply conservation of energy concepts to problem solving.

The student will
8.01 solve motion problems about an object in free fall near the earth's surface using the relationship between potential and kinetic energy.
8.02 solve motion problems concerning one-dimensional inelastic collisions of two objects.
8.03 determine mathematically that the total of the potential energy and kinetic energy remains the same, even when the energy is changed from one to the other.
9. Apply the first and second laws of thermodynamics.

The student will
9.01 state the mathematical relationship between heat, kinetic energy and work.
9.02 describe at least one phenomenon that is explained by the Second Law of Thermodynamics.**
9.03 use a calorimeter to calculate the specific heat of at least two different metals.
9.04 explain steps and proper sequences in the Carnot cycle.**

10. Illustrate the characteristics of transverse and longitudinal waves.

The student will
10.01 generate longitudinal and transverse waves by using a coil spring.
10.02 quantitatively state the relationship between the frequency of a wave and the period of a wave.
10.03 draw a diagram of a transverse wave traveling from one medium to another.
10.04 explain the necessity of a supporting medium to transmit longitudinal sound waves.

11. Apply the properties of light to the functions of mirrors and lenses.

The student will
11.01 diagram light reflecting off a plane, concave, or convex mirror showing the focal point and the location and orientation of the images when given the location and orientation of the object.
11.02 diagram light passing through concave or convex lenses showing the focal point and the location and orientation of the image when given the location and orientation of the object.
11.03 identify and apply factors in refraction of light including indexes of refraction.**
11.04 calculate the index of refraction for any medium, given the speed of light in the medium.
11.05 identify similarities and differences between theories of light propagation.**
11.06 recognize patterns resulting from various diffraction gratings.
11.07 state the contributions of Roemer, Michelson, Moreley and Huygens to our understanding of the velocity of light.

12. Distinguish between static and current electricity.

The student will
12.01 describe basic characteristics of static electricity.
12.02 quantitatively compare the force between two charged bodies and the distance between their centers of charge.
12.03 define any motion of electrical charges in terms of electric current.
12.04 solve for an unknown resistance using a Wheatstone Bridge.

** Standards of Excellence

The student will
13.01 calculate the unknown variable (voltage, current, or resistance) when given the other two.
13.02 calculate the work done in transferring a given charge through a given potential difference.
13.03 calculate the total resistance of a simple parallel or series circuit containing resistors.
13.04 solve for an unknown resistance using a Wheatstone Bridge.**
13.05 quantitatively state the relationship between the heat developed in a conductor, the current through the conductor and the resistance of the conductor.


The student will
14.01 quantitatively state the relationship between the force between two charged bodies and the product of the charges or the distance between the charge centers.
14.02 calculate the force between two spherical charges when given the value of two charges and the distance between their centers.

15. Demonstrate the properties of magnets, magnetic fields and magnetic forces.

The student will
15.01 identify the source of any magnetic field as electrical charges in motion.
15.02 differentiate among ferromagnetism, diamagnetism, and paramagnetism.
15.03 describe any magnet in terms of the magnetic field around it.

16. Demonstrate the meaning of half-life.

The student will
16.01 balance nuclear transmutation equations.
16.02 solve problems in radioactive decay using half-life data.

17. Distinguish between fission and fusion.

The student will
17.01 compare fission and fusion in terms of the initial particles, final particles and relative energy released.
17.02 demonstrate an understanding of measuring various forms of nuclear radiation.

18. Illustrate the applications of nuclear reactions.

The student will

** Standards of Excellence
18.01 give examples of nuclear energy sources.
18.02 give examples of uses of radioactive tracers.
18.03 give examples of military and medical uses of radioactive material.

19. Recognize the numerous particles within the nucleus and other subatomic particles.

The student will
19.01 give examples of more than three subatomic particles.
19.02 discuss the characteristics of electron capture, pair production, annihilation, neutron decay, Bremsstrahlung and Compton scattering.

20. Explain the nature of and transmission of sound.

The student will
20.01 demonstrate the characteristics of sound and sound waves.
20.02 demonstrate and explain resonance in terms of wave interference.
20.03 give examples of production, propagation, reception and detection of sound.
20.04 define and give examples of characteristics of tone and tonal quality.

21. Describe how physics interacts with society and technology.

The student will
21.01 apply the principles of magnetism to computer memory.
21.02 describe career opportunities resulting from the study of physics.
21.03 list five ways in which technological advances affect the individual.
21.04 describe the interdependence of science, technology, and the economy in terms of their processes, growth and development.**
21.05 describe and analyze advantage and disadvantages of various energy technologies.**
21.06 list career opportunities in the field of physics.

** Standards of Excellence
APPENDIX B

Sample Teacher Evaluation Form
TEACHER EVALUATION FORM

1. Each laboratory activity gives the course student performance standard number. Do you feel this is beneficial?

2. Most laboratory activities include a choice of procedure, inductive or deductive. Do you like this choice?

3. Each laboratory activity lists the materials needed and alternate equipment. Do you like this?

4. Do you feel a guide similar to this should be developed for each science course offered in Florida high schools?

5. Activities in the laboratory curriculum are organized numerically by the course student performance standard number. Do you like this?

6. Would you use a guide similar to this one for the courses you teach?

7. Some science concepts may have more than one activity corresponding to it. Do you like being able to choose the activity/activities you will use?

Comments/Criticisms
APPENDIX C

Teacher Comments on Evaluation Forms
TEACHER COMMENTS ON EVALUATION FORMS

1. I like the simple, easy to follow outline form and the fact that materials needed are listed first.

2. State class (chemistry, physics, etc.) and grade level the lab is designed for.

3. Consider having a pre/post lab to enhance the outcome.

4. Overall, I like this type of format because it is short and concise.

5. Showing a data table to be completed would make grading labs much easier.

6. To me, calculations should be part of the procedure.

7. For fundamentals and lower level science courses, the procedure needs more specific instructions.

8. Labs should be written for teacher use to be implemented in class or written so students can use them directly.

9. How much is taught or gone over ahead in the classroom?

10. Is this for student or teacher only use?

11. Every little bit helps in meeting the standards.

12. I liked the layout of your lab on measurement and accuracy. This would be an excellent lab.
APPENDIX D

Survey of Physics Teachers at Dreyfuss Workshop
At a Dreyfuss Institute and Woodrow Wilson Foundation sponsored workshop for physics teachers held in June of 1986, a survey was conducted to determine the preferred and mandated aspects of laboratory activities in public and private schools along the East Coast of the United States. The results of this survey are given below.

1. Total number of physics teachers surveyed: 24
2. Total number of states represented: 11
   (Listed below are the number of teachers from each state represented)
   a) Florida 3   g) New Hampshire 1
   b) Ohio 5     h) West Virginia 2
   c) Georgia 2   i) North Carolina 2
   d) Virginia 5   j) South Carolina 1
   e) Maryland 1   k) New Jersey 1
   f) Pennsylvania 1
3. Types of schools represented in the survey:
   a) public 16   b) nonpublic 8
4. Number of public school teachers from each state:
   a) Florida 2   f) Georgia 2
   b) Ohio 3     g) West Virginia 2
   c) Maryland 1   h) North Carolina 1
   d) Virginia 3   i) South Carolina 1
   e) Pennsylvania 1
5. Number of private school teachers from each state:
   a) Ohio 2  
   b) Florida 1  
   c) New Jersey 1  
   d) New Hampshire 1  
   e) Virginia 2  
   f) North Carolina 1

6. Is the curriculum mandated by either the school, district, or state?
   a) yes 11  
   b) no 12  
   c) don't know 1

7. Is a laboratory time requirement in effect?
   a) yes 5  
   b) no 18  
   c) don't know 1

   Of the "yes" answers, the breakdown in time required is as follows:
   a) Florida public school 72 hours/year
   b) Ohio public school 50 minutes/day
   c) Virginia public school 50% of class time
   d) Virginia private school 80 minutes/week
   e) Virginia public school 60% of class time

8. Type of laboratory format utilized:
   a) laboratory manual only 1  
   b) laboratory manual and supplementary materials 22  
   c) devise own laboratories 1

9. Format preferred for laboratory reports:
   a) formal laboratory reports for every experiment completed 14  
   b) mixture of formal and informal reports 8  
   c) no formal reports required 2
10. **Type of laboratory approach preferred:**

   a) inquiry only 5
   b) verification only ("cookbook") 2
   c) combination of inquiry and verification 9
   d) demonstration only 4
   e) misinterpretation of the question 4

**CONCLUSIONS**

Several conclusions can be drawn from this survey of public and private school physics teachers from eleven different states. First, most physics teachers tend to require formal laboratory reports for all experiments completed. Second, most physics teachers use supplementary materials in addition to the laboratory manual that accompanies the textbook adopted. Third, many physics teachers prefer to use a variety of laboratory approaches instead of utilizing one method consistently.

The survey did tend to support the prediction made in this project that teachers prefer to select laboratory experiments from many sources (i.e. supplement the materials adopted for classroom use by the schools). Physics teachers also prefer laboratory experiments that
allow for teacher preference as to approach used (inductive versus deductive). Another conclusion that could be drawn was that a laboratory experiment that provided a selection for the format of the laboratory report to be written was appreciated by the teachers.