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Scope of Study: Testing of work covered in the high school physics laboratory seems, at the present time, to be an unusual practice. On the basis that a systematic, objective method of evaluating laboratory work will be of material benefit to both students and instructor, this study has developed a series of ten tests which cover a major part of the work commonly found in high school physics laboratories. It also points out the specific advantages to be gained from the use of such a test battery. Resource materials used were chiefly drawn from the author's own experience in teaching the subject and from standard high school physics laboratory manuals.

Findings and Conclusions: To test material covered in laboratory work the test should adhere to a set of objectives. It should refer to things which are better learned in laboratory work than in the classroom. It should confront the student with actual laboratory equipment and situations. It should test his grasp of the principles studied as well as his grasp of scientific method. On these bases it was concluded that the tests should be in the form of performance tests. These include several stations per test, at each of which the student is presented with a task or problem and the necessary equipment to solve the problem. It is felt that in this way the objectives for the tests and for the laboratory itself may be met.

ADVISER'S APPROVAL James H. Zant

LABORATORY TESTING OF CLASSES

IN HIGH SCHOOL PHYSICS

By

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CHAPTER I

THE PROBLEM: ORIGIN AND DESCRIPTION

Evaluation of work in the high school physics laboratory is currently being done in nearly as many ways as there are high school physics teachers. This becomes evident when a group of them begin to talk shop at a teachers' convention or other gathering. In addition to conventions it has been the author's good fortune to be placed in positions enabling him to contact many more physics teachers than is normally the case. During the summer of 1954 he was a participant in a seven week program at The Case Institute of Technology with forty-nine other physics teachers, while the present academic year has again made possible a great many contacts with teachers of high school physics. All of this has brought about an awareness of the diversity of methods used in evaluation of high school physics laboratory work and a desire to formulate some specific means for evaluating the work of the students.

Need for the Study

Laboratory work takes up a substantial portion of the time devoted to the high school physics course. Therefore, it would seem reasonable that some regular, systematic method of objectively determining the student's progress in the laboratory should be made. Methods of checking this progress such as the inclusion of a few questions over the laboratory work on the regular examination or the purely subjective method of observing a student's progress as he works seem to this writer to be only halfway measures. The checking of reports of experiments done which students write and hand in also has many disadvantages which are familiar to every teacher of the subject. With these thoughts in mind it has seemed an entirely logical conclusion that a set of tests should be devised which could be administered at more or less regular intervals and which would show objectively the student's progress.

Not only do tests appear to be the best means available for the evaluation of student progress but there are also certain other advantages which may be of direct benefit to the instructor and to the students. The first of these would be that a testing program forces the instructor to look more critically at the way his laboratory is conducted. It may well cause him to construct a set of objectives for laboratory work where none existed before. It may also cause him to look twice at the distribution of time as it is being spent on the different topics. It will certainly force the instructor to decide what are, to him, the important points to be learned during the laboratory period, for these are precisely the points which will appear in his tests.

Another advantage to be gained from the testing program is the effect regular testing has on the students in a class. Motivation to learn must certainly come partly from the instructor's method of presentation and partly from the subject matter itself. There is, however, no better means of motivating the student to look back and take stock of what he has learned and is learning than to instill in him the fact that his instructor thinks a review important enough to give tests based upon the work of a unit or section.

It seems to the writer that the arguments outlined above point conclusively to the need for a study such as this; a study culminating in a set of tests for the high school physics laboratory which bring to bear all the backlog of experience which can be mustered, both personal and from other sources.

Available Literature

The author, after an extensive study of educational bulletins, periodicals devoted to science and science teaching, books and other library sources, was forced to conclude that any work on testing of high school physics laboratories has either not been attempted or is not available at this time. A few articles was found, however, on such work on the college level. Wall, Kruglak and Trainor published an excellent article on laboratory performance tests as conducted at the University of Minnesota.[1] Carl E. Adams in a letter to the editors of the American Journal of Physics has presented an outline of a laboratory practical test which he administered to college students in elementary physics.[2] These have been helpful in that they helped, in some measure, the determination of the form which the tests would take. Mainly, however, the material has had to be drawn from the backlog of experience which the author has accumulated over the past several years of teaching high school physics.

[1] C. N. Wall, H. Kruglak, and L. E. H. Trainor, "Laboratory Performance Tests at the University of Minnesota," American Journal of Physics, 1951, IXX, 546-555.

[2] Carl E. Adams, "Letters to the Editor," American Journal of Physics, 1952, XX, 184-185.

Method of Procedure

As mentioned previously, the construction of a set of tests over a certain body of subject matter forces the author to look critically at the way the laboratory is operated. It has been necessary in this case to construct a set of objectives which the tests should follow in all instances. It has also been necessary to divide the material usually covered in laboratory work into segments which were coherent in their subject matter and which would provide material for tests of approximately equal length. The format of the tests was determined in the light of the objectives and of workable practicality.

CHAPTER II

THE TESTS: A DESCRIPTION AND ANALYSIS

Two sets of objectives were set up before actual work on the construction of tests could begin.

Objectives for the Laboratory

The first of these was a set of objectives for the laboratory work itself which the tests would attempt to evaluate.

1. To become familiar with equipment and/or instruments involved.
2. To acquire the necessary skills involved in the manipulation of the instruments.
3. To make use of the knowledge gained in regular class and to aid in the reinforcement of this knowledge.
4. To prepare the student for more advanced courses in the subject.
5. To develop scientific ways of thinking.
6. To make use of the elements of scientific method.

Objectives for the Tests

The second set of objectives covered the tests themselves and were set up to help determine the format and the method of testing.

1. To test skills and knowledge which are better learned in the laboratory than in the classroom.
2. To test the students ability to think scientifically.

3. To confront the student with actual laboratory equipment and situations.

4. To aid in the direction of the students' study habits along desirable channels.

Format

The objectives for the laboratory and for the tests themselves seemed to dictate a type of test which was out of the ordinary, that is a strictly essay type or a strictly objective, short answer type seemed impractical. As finally decided upon the tests are performance type tests. In each test a number of stations are described. These stations are to be set up, each in its own particular area of the laboratory, are to contain the apparatus as listed and the student is to follow the directions for that station within the time allotted. In general the time limits seem to the author to be generous so that the tests should not be speed tests. An attempt has been made to make the equipment of the type which is not easily broken or put out of order, thus, cutting down the extreme amount of supervision which would otherwise be required. The number of stations per test has been set so that the student can complete the work at each one within a fifty minute laboratory period. There would, of course, be two or more of each station in order that each student in the class could work simultaneously.

It is believed that the subject matter covered by the tests include the great majority of experiments which are usually included in the standard high school physics course. The tests each cover about the same amount of material and would be distributed at approximately equal intervals of time throughout the year. It is the author's firm belief that, if used as proposed, these tests will provide a meaningful learning device for the students in their laboratory work, will help the instructor to establish a sense of direction in his own work in the laboratory and will provide a firmer basis for the evaluation of laboratory work than has heretofore been possible.

CHAPTER III

THE TESTS

TEST 1. MEASUREMENT

STATION 1 - (8 minutes)

APPARATUS: Meter stick, piece of wood or iron at least 25 cm. long and another over 1 meter long, standard yard stick graduated to 1/16's of an inch.

DIRECTIONS: Use the above materials to answer the following questions.

1. What is the length, to the nearest significant figure of the short piece of wood?

Answer in inches______________________.

Answer in cm._________________________.

Answer in meters______________________.

Answer in mm._________________________.

2. What is the length, to the nearest significant figure, of the long piece of wood?

Answer in cm._________________________.

Answer in meters and cm.______________.

Answer in meters, cm., and mm._______.

Answer in feet and inches_____________.

3. Which do you believe to be the most accurate way to measure, with the meter stick or with the yard stick?________________.

Why?____.

STATION 2 - (8 minutes)

APPARATUS: Vernier caliper, rectangular metal or wooden block, hollow metal or wooden cylinder.

DIRECTIONS: Make all answers to the nearest significant figure. Answer first in English and then in metric units.

1. What is the length of the block?________________________.

________________________.

2. What is the outside diameter of the cylinder?___________.

___________.

3. What is the inside diameter of the cylinder?____________.

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4. Which of your figures is more accurate, the English or metric?____.

Why?____.

STATION 3 - (8 minutes)

APPARATUS: Micrometer caliper, metric; micrometer caliper, English; small metal cylinder, piece of sheet metal.

DIRECTIONS: Make all measurements to the nearest significant figure in both the English and metric systems.

1. What is the diameter of the cylinder?___________________.

___________________.

2. What is the thickness of the piece of sheet metal?_______.

_______.

3. Which of your figures are more accurate, English or metric?

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Why?____.

4. What is the purpose of the ratchet on the end of the micro-

meter?____

____.

STATION 4 - (8 minutes)

APPARATUS: Triple beam balance or trip balance and set of weights; 2, 100 ml. beakers marked A and B; 50 ml. burette mounted on stand, alcohol.

DIRECTIONS: You have all the apparatus necessary to answer the following questions. Give measurements to the nearest significant figure.

1. What is the weight of beaker A?__________________________.
2. What is the weight of 40 ml. of alcohol?__________________.
3. What is the density of the alcohol?_______________________.

STATION 5 - (8 minutes)

APPARATUS: 100 ml. graduated cylinder; irregular shaped objects which will fit into the cylinder labeled A and B; water, triple beam balance.

DIRECTIONS: You have all the apparatus necessary to answer the following questions. Give all answers to the nearest significant figure.

1. What is the weight of object A?__________________________.
2. What is the volume of object A?__________________________.
3. What is the density of object A?_________________________.
4. What is the weight of object B?__________________________.
5. What is the volume of object B?__________________________.
6. What is the density of object B?_________________________.

TEST 2. BUOYANCY AND SPECIFIC WEIGHT

These are tests of speed and accuracy. You will be allowed exactly ten minutes at each station. The test must be turned in at the end of the period.

STATION 1 - (10 minutes)

APPARATUS: Balance supported above table; overflow can; catch bucket; battery jar nearly full of water; metal block or cylinder, thread.

DIRECTIONS: Using the apparatus at this station verify Archimedes' Principle. Record all data. ____________________

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STATION 2 - (10 minutes)

APPARATUS: Balance; overflow can; catch bucket; battery jar nearly full of water; wooden block or cylinder, thread.

DIRECTIONS: Using the apparatus at this station verify Archimedes' Principle. Record all data. ____________________

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STATION 3 - (10 minutes)

APPARATUS: Balance mounted on support; metal block or cylinder;

thread; labeled battery jar containing water; battery jar containing carbon tetrachloride, labeled.

DIRECTIONS: Using the materials at this station, determine the specific gravity of carbon tetrachloride. Record all data.________

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STATION 4 - (10 minutes)

APPARATUS: Hydrometer jars labeled A,B,C and D and filled with water, alcohol, saturated solution of salt water and dilute sulfuric acid, respectively; hydrometers for low and high density liquids, battery hydrometer.

DIRECTIONS: Answer each of the following questions as accurately as possible. Use the battery hydrometer only on jar D.

1. What is the specific weight of the liquid in jar A?______
____.

2. What is the density of the liquid in jar B?______________
____.

3. What is the density in the English system of the liquid in jar C?_______________________________________.

4. Does the acid in jar D have a density higher or lower than that in a fully charged storage battery?___________________.

TEST 3. BOYLE'S LAW AND HOOKE'S LAW

STATION 1 - (12 minutes)

APPARATUS: J-tube apparatus; mercury; medicine dropper, funnel to fit the J-tube.

DIRECTIONS: Check to make sure that the mercury at the base of the J-tube rises to the same height in each of the two arms of the tube. If it does not, make it do so before beginning the experiment. Be sure to remove watches and other jewelry before beginning. When completed you will remove the mercury you have added and level the height in the two arms to prepare it for the next student. Your instructions are to determine from this apparatus the pressure of the air in the room as accurately as possible. Record all data and outline your procedure.

STATION 2 - (12 minutes)

APPARATUS: Hooke's Law apparatus; a 100 gram and a 200 gram weight, object of indeterminate weight but which will not exceed the elastic limit of the spring.

DIRECTIONS: Apply Hooke's Law and determine the weight of the unknown. Record all data and outline your procedure.

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TEST 4. FORCES AND PENDULUMS

STATION 1 - (15 minutes)

APPARATUS: 2 spring balances and a spring such as is used in Hooke's Law experiments. The balances and the spring are connected by string and are set up so as to act on a common movable point. The whole then demonstrates three forces in equilibrium with two of them known. The angle between the balances should be between 30° and 60°.

DIRECTIONS: Using your ruler, protractor and pencil, determine the tension in the spring as accurately as possible. Do not move the apparatus and leave it exactly as you found it. Record all data and show any diagrams used in the space below.

STATION 2 - (15 minutes)

APPARATUS: Meter stick with clamp; meter stick support; 200 gram weight, thread.

DIRECTIONS: Using only the materials given locate the center of gravity of the meter stick and determine its weight. Make full use of your knowledge of moments of force and of torques. Outline your procedure and record all data.

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STATION 3 - (15 minutes)

APPARATUS: Stop watch; meter stick; three simple pendulums with bobs of varying weights mounted in a pendulum clamp, the longest should be a little over a meter in length. The second pendulum is about three-fourths as long as the first and the third is about half as long as the first.

DIRECTIONS: Using the above materials determine the following points.

1. Determine the frequency of the longest pendulum at low amplitude.

Frequency equals____________________.

2. Using only the meter stick (not the stop watch) determine the frequency of the middle sized pendulum.

Frequency equals____________________.

3. Using only the stop watch (not the meter stick) determine the ratio of the length of the longest pendulum to that of the shortest.

The ratio is________________________.

TEST 5. MECHANICAL ADVANTAGE, SIMPLE MACHINES, AND HORSE POWER

STATION 1 - (10 minutes)

APPARATUS: Meter stick mounted in clamp, clamp attached at 15 cm. mark; standard laboratory wheel and axle apparatus mounted on a stand with counterbalancing weights attached by string to the smallest and largest diameters.

DIRECTIONS: Answer the following questions about the material at this station.

1. Assuming that the meter stick clamp acts as a fulcrum and that the effort force and resistance force are located at the ends of the meter stick, what is the largest theoretical M.A. possible?________________________________.

2. What is the smallest theoretical M.A. possible?________.

3. The effort force acts upward at the 100 cm. mark. Which is greater, the actual or the theoretical M.A.?____________.

4. If the weight on the largest diameter of the wheel and axle is the effort force what is the actual M.A. of this machine?________________________________.

5. If the rear wheel of an automobile had the same diameters of effort and resistance forces as does this one, how far would the car move when the effort moved 3 ft.?________________.

STATION 2 - (10 minutes)

APPARATUS: Meter stick; set of slotted weights; vernier caliper; lag screw, 3 inches long; block of wood cut into a wedge; 2 pulleys with 2 sheaves each, mounted with string so that the effort force is pulling downward and completely counterbalanced with weights.

DIRECTIONS: Answer the following questions using the materials at this station.

1. What is the pitch of the lag screw?________________.

2. Considering the lag screw as a simple machine what is its theoretical M.A.?________________.

3. What is the theoretical M.A. of the wedge?________________.

4. What would normally be considered a probable actual M.A. for the wedge?________________.

5. What is the theoretical M.A. of the pulley system?______.

6. What is the actual M.A. of the pulley system?__________.

STATION 3 - (20 minutes)

APPARATUS: Ladder extending from the floor to the ceiling; stop watch; meter stick or tape rule, scales.

DIRECTIONS: You will work in pairs to obtain the data for this station. Answer the following questions.

1. What is the height of the ceiling?________________.

2. What is your own height?________________.

3. What is your weight?________________.

4. How long does it take you to climb the ladder and touch your head to the ceiling?________________.

5. What is the length of the ladder?________________.

6. What is the theoretical M.A. of the ladder as a simple machine?________________.

7. What average force did you use in climbing the ladder?____ ________________.

8. What horse power did you develop in climbing the ladder? ________________.

TEST 6. HEAT

STATION 1 - (8 minutes)

APPARATUS: Thermometer; snow or finely cracked ice in funnel, beaker to catch melted ice or snow.

DIRECTIONS: Determine the ice point correction for the thermometer at this station.

Correction________________________.

STATION 2 - (8 minutes)

APPARATUS: Steam boiler complete with water and heat source; thermometer; up to date barometric pressure is to be furnished.

DIRECTIONS: Compute the true steam point for the thermometer at this station.

True steam point____________________.

STATION 3 - (8 minutes)

APPARATUS: Wet and dry bulb hygrometer in working condition; relative humidity tables, table of water vapor capacity of air.

DIRECTIONS: With the apparatus at this station determine both the relative and the absolute humidity.

Relative humidity___________________.

Absolute humidity___________________.

STATION 4 - (10 minutes)

APPARATUS: Pencil and paper.

Directions: Work the following problem at your seat.

A student obtained the following data from an experiment to determine the heat of fusion of water:

1. Wt. of calorimeter--50 gm.
2. Sp. ht. of calorimeter--0.1.

3. Wt. of calorimeter and water--200 gm.

4. Initial temperature of water--30°C.

5. Final temperature of water--15°C.

6. Wt. of ice added to cool water--30 gm.

From these data determine the students experimental error for the heat of fusion of water.

Experimental error____________________.

TEST 7. SOUND

STATION 1 - (15 minutes)

APPARATUS: Resonance tube of the type in which the water level may be rapidly adjusted; tuning fork of unknown frequency; ruler or meter stick, thermometer.

DIRECTIONS: Using the apparatus at this station, determine the frequency of the tuning fork. Make all calculations as accurate as possible and record all data in the space below.

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STATION 2 - (15 minutes)

APPARATUS: 2 bridges for changing the effective length of a string; sonometer with 3 strings the same diameter stretched as follows: 1) The first string to 6 kilograms tension; 2) the middle string to 10 kilograms tension, and 3) the third string stretched to 15 kilograms tension,

DIRECTIONS: Answer the following questions about the sonometer.

1. Which string has the highest pitch?____________________.
   Why?____________________________________
   ______________________________________.

2. With a bridge placed at the middle of the string with the

least tension, which string has the highest pitch?__________.

Why?____

____.

3. Place one bridge $\frac{1}{4}$ of the way from one end of the middle string and leave the bridge of question 2 in place. Which string now has the lowest pitch?___________________________.

Why?____

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STATION 3 - (15 minutes)

APPARATUS: Tuning fork and pendulum, each mounted with a stylus attached so that their vibrations may be recorded simultaneously on a smoked glass plate.

DIRECTIONS: Assume that the pendulum makes 4 complete vibrations per second. Determine the frequency of the tuning fork. Make at least three trials and record the results of each trial and the final average in the space below.______________________________

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TEST 8. LIGHT

STATION 1 - (15 minutes)

APPARATUS: Plane mirror attached to wooden block so it will stand upright; ruler; protractor, pins.

DIRECTIONS: With the apparatus at this station obtain the data which will prove the first law of reflection. Record the data and state the method used in the space below.

STATION 2 - (15 minutes)

APPARATUS: Thick rectangular glass plate; ruler; pencil compass; pins, protractor.

DIRECTIONS: Using the apparatus at this station determine the index of refraction of the glass plate. Make a drawing to illustrate the method used and record all the data obtained.

STATION 3 - (15 minutes)

APPARATUS: Double convex lens mounted on meter stick; cardboard screen also mounted on the meter stick. The distance between the lens and the screen must be adjustable.

DIRECTIONS: Using this apparatus determine the exact focal length of the lens. You may move the meter stick, the lens or the screen in any way necessary for the completion of this problem. Outline the procedure used and the data obtained in the space below.

TEST 9. MAGNETISM AND STATIC ELECTRICITY

STATION 1 - (10 minutes)

APPARATUS: Bar magnet mounted in a support free to pivot horizontally; bar magnet, unmounted, iron bar exactly like the two magnets except unmagnetized. No pole markings should appear on the bars but each should have the ends labeled with different letters, A,B,C,D,E,F.

DIRECTIONS: Answer the following questions.

1. Which end of the pivoted magnet is a north pole?________.

2. Which of the other two bars is a magnet?_______________.

How do you know?____.

3. Which end of the unsupported magnet is the north pole?___.

How do you know?____.

4. Can you prove that one of the bars is not a magnet?______.

How?____

____.

STATION 2 - (10 minutes)

APPARATUS: Vulcanite rod; cat's fur, gold leaf electroscope.

DIRECTIONS: With the apparatus at this station charge the electroscope negatively and then positively. State clearly in the space below how you can prove each type of charge.

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STATION 3 - (10 minutes)

APPARATUS: Permanent bar magnet with the poles marked; magnetic compass, unmagnetized needle.

DIRECTIONS: Magnetize the needle so that the pointed end forms a south pole. Pin the needle to this sheet and state a method by which you can prove that the pointed end is a south pole.

TEST 10. CURRENT ELECTRICITY

STATION 1 - (10 minutes)

APPARATUS: An electrical circuit containing 2 dry cells connected in parallel; 2 flashlight bulbs, $1\frac{1}{2}$ volt, connected in parallel with each other and in series with the dry cells; an electric bell connected in series with the bulbs and with the cells; switch for turning the entire circuit on or off; voltmeter connected across the dry cells and an ammeter in series with the entire circuit.

DIRECTIONS: Draw a schematic diagram of this circuit. Label all components and show the polarity of cells and instruments for which polarity is significant.

STATION 2 - (10 minutes)

APPARATUS: Wheatstone bridge circuit including unknown resistance marked "A"; labeled known resistance, galvanometer.

DIRECTIONS: Do <u>not</u> change the setting of the resistance box.

Determine the resistance of the unknown resistor "A". Show all your calculations.

STATION 3 - (10 minutes)

APPARATUS: AC voltmeter and ammeter connected into a circuit containing an on-off switch; an electric iron or other appliance, connected to a 110 volt outlet.

DIRECTIONS: In the space below determine the wattage used when the circuit is closed.

STATION 4 - (10 minutes)

APPARATUS: Electroplating apparatus containing copper sulfate solution; a copper plate; an object to be plated, a dry cell.

DIRECTIONS: Draw a diagram in the space below showing how the components given should be connected to cause copper to be plated on the object. Be sure to label all parts and show the polarity where it is important.

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