Laboratory Manual to Accompany

PHYSICS IN THE MODERN WORLD 2E

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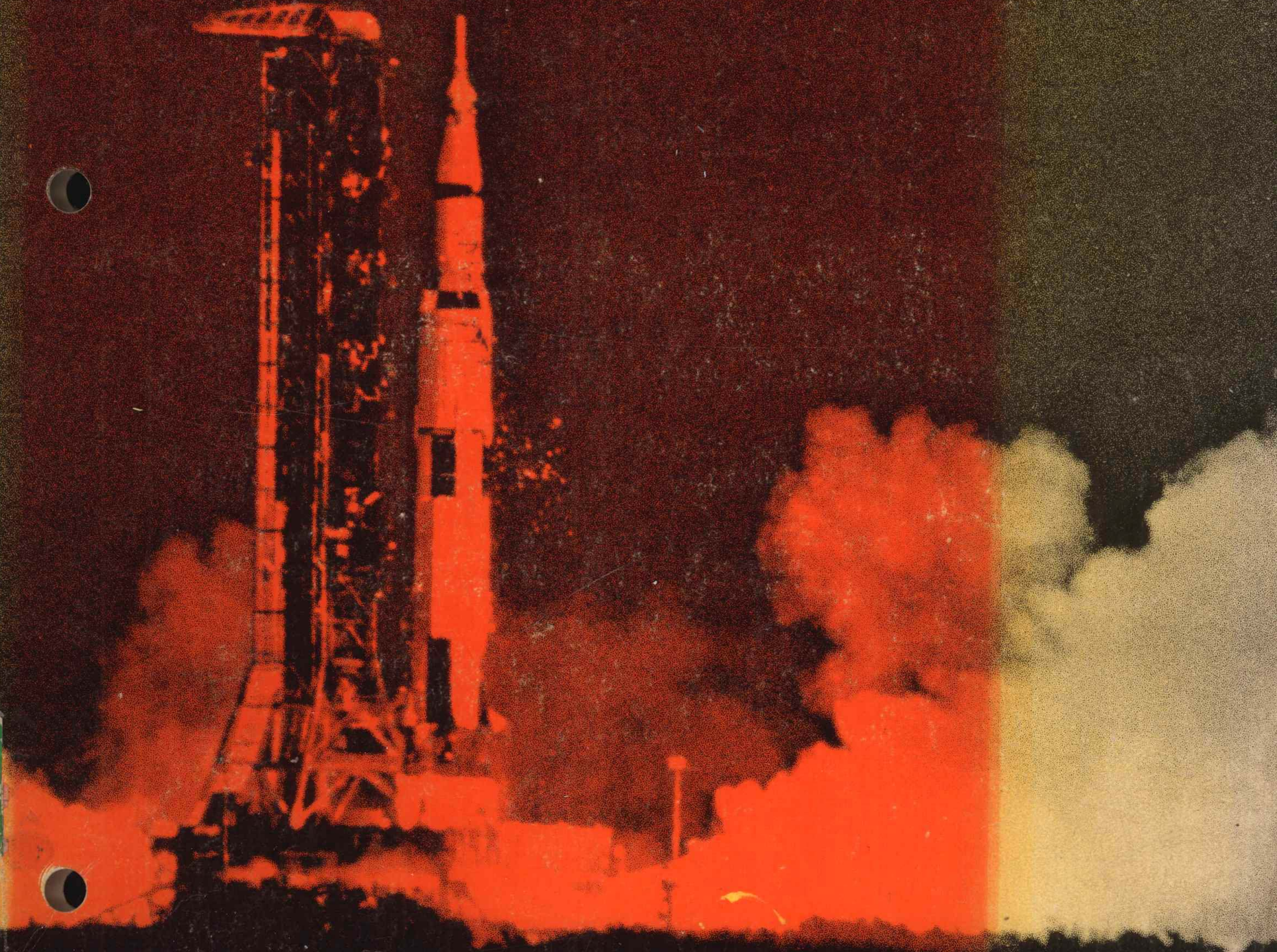

LABORATORY MANUAL
to accompany

PHYSICS IN THE MODERN WORLD
Second Edition
by Jerry Marion

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Academic Press, Inc.
111 Fifth Avenue, New York, New York 10003

United Kingdom Edition published by
Academic Press, Inc. (London) Ltd.
24/28 Oval Road, London NW1

ISBN: 0-12-472286-5

Manufactured in the United States of America

PREFACE

All of the experiments in this manual have been used in many introductory physics courses* for many years. The advantage of this manual is in its organization of the material and in its focus in using these basic experiments to lead students from purpose to conclusion to give a satisfying, unified laboratory experience. While the manual is usable with any introductory physics text, the order given is specifically coordinated with the study of the text Physics in the Modern World by Jerry B. Marion, published by Academic Press, Inc.

The first ten experiments are on the general topic of Mechanics. Experiment 1 fits well with Chapter 1 and then Experiments 2 and 3 are designed to introduce the concepts of velocity and acceleration as they appear in Chapter 2. Experiments 4, 5 and 6 relate to Chapter 3 on Force, and Experiment 7 to Chapter 4 on linear momentum. Experiment 8 introduces circular motion for Chapter 5 and Chapter 7 on Energy is introduced by Experiments 9 and 10.

The second block of experiments, on Electricity and Magnetism, is introduced by two experiments on static electricity and the order of Experiments 13 - 20 fits well with the order of the material in Chapters 11 and 12.

The final ten experiments on Waves, Light and Optics are introduced by Experiment 21 - Waves on a Spring, and then this is followed by Experiments 22-25, all ripple tank experiments that cover the study of water waves in reflection, refraction, diffraction and interference (Chapter 13). A repeat of these experiments replacing water waves with light waves occurs in Experiments 26 - 30 and can be well coordinated with the text (Chapter 15).

Each of the three parts of this manual contains experiments dealing with one branch of physics and can be treated as an independent unit. Any part can fit well into an introductory term course on one of these three general topics. There are no experiments on heat or on fluids. Unless excellent equipment is available and great care taken, experiments on heat often have unsatisfactory results and experiments on fluids, especially involving the gas laws, are usually incorporated in introductory chemistry courses.

In almost all cases the experiments should be done by the students before lectures or reading on the subject involved. This is to allow the students the opportunity and the challenge of figuring out relationships for themselves by observation and analysis of data. The manual, like the text, gives an introduction to physics to college students, but they can both be used very effectively with able high school students.

All of the experiments have been planned so that the collection of data for each experiment should be accomplished in 50-60 minutes, especially if the student has read the directions carefully in advance and, if possible, had a brief preview of the equipment and the techniques to be used in the experiment. In a double period, it should be possible to complete the collection of data, graph, if required, analyze the data and check it, if necessary. If only a single period is available, the data can be collected in the laboratory and the analysis done outside. In either case, a short post-lab discussion is of great value after the data has been analyzed.

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* The ripple tank experiments on waves, many optics experiments and a few others are similar to the experiments included in the Physical Science Study Committee course.

In general, the experiments will average one a week throughout a year's course. There is an exception in Part III. With the ripple tank experiments, Experiments 22-25, an open-lab situation for two weeks is ideal for allowing students to spend as much or as little time on these valuable experiments as they need. There will be two experiments a week in this case whether in regular laboratory periods or in open-lab. This means that there are no experiments planned for the last weeks of the course. This omission is intentional, because the subject matter of this section of the course is usually relativity, photoelectric effect, quantum theory, structure of matter, nuclear power, radiation, etc. and equipment is so varied that few experiments are appropriate for use in most physics laboratories. Some related experiments that are of value, if the equipment is available, are ones on photoelectric effect, solar cells, radioactive decay and the measurement of half-life, the use of lasers and the production of holograms.

It will be noted that the equipment used in most of the experiments in this manual is very simple. Although much more sophisticated equipment is available, the basic principles are easier for the students to recognize, understand and appreciate if they can see and handle simple materials. It is strongly suggested that the simple apparatus be used in the laboratory and the more complicated equipment be used in demonstrations for the introductory course and in upper level laboratory experiments.

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GENERAL LABORATORY DIRECTIONS

INTRODUCTION

When you discover a relationship for yourself, you are much more apt to appreciate it and remember it than when someone tells you about it. Learning by doing, by investigation, is much more rewarding and is also more fun than any other type of learning experience.

The laboratory work that you will be doing this year is, in part, to help you develop skills in lab technique, but it is primarily to lead you to find out for yourself the basic relationships that make up the study of Physics. Almost every physical concept is a mathematical relationship, the dependence of one variable on another; for example, how distance covered varies with time and velocity, the effect of force on acceleration, relationship of wave length to frequency, etc.

When you go into the laboratory, you will not be setting out to verify laws or try to prove, by exact measurement, what some scientist has proposed as cause and effect. You will, instead, be trying out variations, looking for relationships, as you change one variable and study the effect of these changes on another variable. Almost every new subject will be introduced with a laboratory project that will give you the opportunity of tracking down a relationship. Sometimes this will be obvious and expected - the faster you go, the more ground you cover - simple direct proportion. But at other times, the exact mathematical relationship may be more difficult to spot. Graphing and graph analysis will be very useful and valuable tools.

FORM OF LABORATORY REPORTS

All laboratory reports are to follow the same general format and the report pages at the end of each experiment in this manual are to be used in the presentation of the reports. The subdivisions of the presentation are here described and this should be read very carefully before the first experiment is done.

It is not necessary to include method, procedure or list of equipment used because they will be adequately described in the directions and you can always refer to them.

PREDICTION: This is not required, but can add to the experiment. It is your guess as to the outcome and is based on your knowledge, common sense and previous experience.

DATA: Here, carefully listed or charted should be all of your original data. Never take down readings on scraps of paper or edges of pages of books, later to copy them into your report. You may sometimes want to copy over your data to improve the form or order for convenience, but this must always be with the original data, never substituted for it. When possible, and time permits, repeat an experiment or part of it to get second readings. This enables you to use the average in your analysis of the data. If there is a large difference between two readings it is wise to take a third. In general, the more readings that are taken the more accurate the average becomes.

Usually your data will be quantitative (in numbers) but do not neglect to mention qualitative data (descriptions of what occurs) if it is appropriate. Care must be taken in accurately describing and labeling all data.

All numbers, except ratios, must have units given. Be alert, also, to significant figures. Do not claim greater accuracy than your measurements allow, but do estimate to tenths when possible - with millimeters or degrees, etc. Significant figures include all that you are absolutely sure of plus one that is an estimation. Usually you should carry three significant figures through your calculations and round off to two, if necessary, for your final result. Always use proper scientific notation (powers of ten) for large and small numbers.

CALCULATIONS AND ANALYSIS OF DATA: These will often be combined and will include, or be supplemented by, graphs, Care and accuracy in graphing will greatly aid your analysis of data. See section on Graphing at end of General Laboratory Directions.

CONCLUSION: This must always relate to the Purpose. It may go beyond the Purpose if you have found out information that you had not expected, but be sure that the Conclusion always answers the question or directly responds to the Purpose. You may also want to respond to your Prediction - recognizing a good guess or explaining why the result did not fulfill your prediction.

After the Conclusion you will sometimes want to add suggestions for other experiments that could be done to reinforce the findings or to check them, or you may want to question the accuracy of your results and suggest improvements or changes in the experiment.

Note to Instructor: Some of these experiments lend themselves well to class laboratory experiments with the instructor doing the experiment as a demonstration, with help from students when appropriate, and the group collecting class data. Each student should do the analysis of data and form a conclusion. If laboratory equipment is limited in any areas, this is a good solution and students like the change and benefit from the discussion during the experiment.

The equipment list that is found at the end of the individual laboratory directions, is, in general, suitable for two students and in most cases it is necessary for the students to work in pairs, especially where timing is a factor. In a few cases students can work alone and where equipment is limited, three or more students can work together. In experiments that are done as demonstrations, only one set-up is necessary for each class.

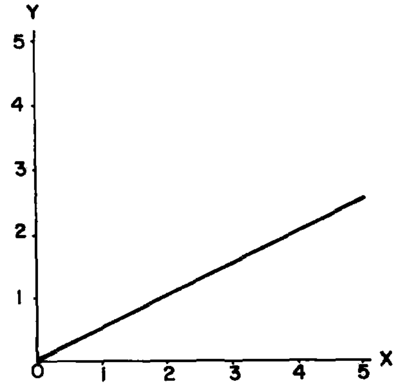
GRAPHING

If you are told to graph one variable against or versus another, the first named is to go on the vertical axis, (ordinate) and the second named is to go on the horizontal axis (abscissa). If you are not told specifically the order, use the horizontal axis for the independent variable, the one that is undergoing controlled change. The dependent variable goes on the vertical axis. A graph is a picture of a relationship; it shows you how one quantity varies with another. A direct proportion is a straight line. An inverse proportion will give a curve and any exponential relationship will also give a curve. The inverse square relationship is not uncommon in Physics. If a first graph is a curve, it is often helpful to then graph one quantity against the square or inverse of the other to see if a straight line then occurs.

To "read" a graph, in other words to analyze the relationship indicated by a graph, it is necessary to <u>see</u> how one quantity (y) varies with another (x).

If the graph shows an ascending straight line as in Graph 1, it means that y increases directly as x increases. We say that y is directly proportional to x, or $y \propto x$.

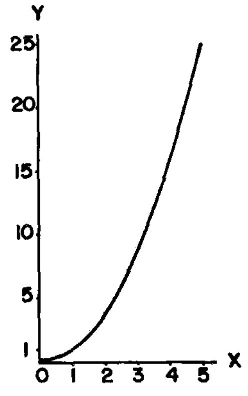
x	y
1	0.5
2	1
3	1.5
4	2



Graph I

If a graph shows a curve as pictured in Graph 2, y is proportional to x^2, or $y \propto x^2$.

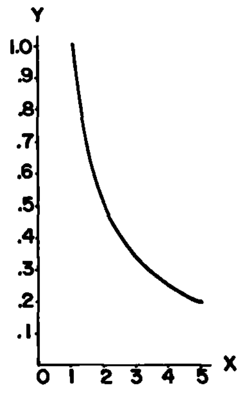
x	y
1	1
2	4
3	9
4	16



Graph 2

If a graph shows a curve as in Graph 3, y is proportional to 1/x, or $y \propto 1/x$.

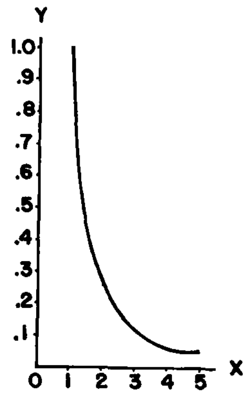
x	y	or	
1	1		1
2	1/2		0.5
3	1/3		0.33
4	1/4		0.25



Graph 3

If a graph shows a curve as in Graph 4, y is proportional to $1/x^2$, or $y \propto 1/x^2$.

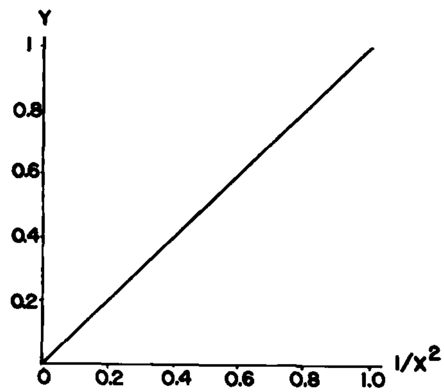
x	y	or	
1	1		1
2	1/4		0.25
3	1/9		0.11
4	1/16		0.06



Graph 4

When you graph your experimental data and you suspect, from the shape of the curve, that a certain relationship exists, it is then possible to graph y against the expression of x that you think is appropriate. For example, if you think that y is proportional to $1/x^2$, you can check the relationship by graphing y versus $1/x^2$. In Graph 4, when x=1, y=1; x=2, y=0.25 etc., if you graph $y \propto 1/x^2$ you would use the following values for Graph 5.

x	$1/x^2$	y
1	1	1
2	0.25	0.25
3	0.11	0.16
4	0.06	0.06



Graph 5

EXPERIMENT 1

Collection and Analysis of Data

INTRODUCTION

In this experiment you will be looking for factors relating the size of a hole in the bottom of a can, the depth of water and the time it takes to empty the can of water. It will give you the chance to try out the investigative approach that you will be using all year, complete with graph analysis.

PROCEDURE

It is best to work in pairs, measuring the time it takes to empty the cans. Collect data for four different hole diameters for each of four different depths of water, using the 1/4 can marks. The smallest diameter and depth can be used as units of measurement, for the other three dimensions are multiples of these. If time permits, take a second reading of any specific depth or diameter situation that you suspect may not be accurate because it does not fit apparent trends. If you take two or more readings for any one situation, use the average value in your final analysis.

DATA

Take down all of your readings as original data in the table provided and then put the averages in the chart.

ANALYSIS OF DATA

Graph your results, referring to General Laboratory Directions for instructions on graphing. Independent variables will be size of hole (diameter) and depth of water in the can. Time is the dependent variable and will depend, of course, on these two factors.

A. Using a scale that utilizes at least 2/3 of the sheet of graph paper, plot the time, (t), versus the depth, (h), for each diameter, (D), used. Do four graphs on one sheet, using the same set of axes, connecting points in a smooth curve for each and labelling them D_1, D_2, D_3, D_4.

B. On a second sheet of graph paper, plot the time, (t), versus diameter, (D), for each value of depth, (h). Connect the points in a smooth curve and label the curves h_1, h_2, h_3, h_4.

C. Are there other possible graphs that would help you to analyze the data?

CONCLUSION

What type of relationship do you see between the time and diameter? Is it direct or inverse? Can you draw any other conclusions? What is the relationship between time and depth?

EQUIPMENT LIST

1 one pound coffee can with top and bottom removed. If available, use cans with ridges at every 1/4 can.

4 plastic covers to fit bottom of coffee can, each with a hole in the center. The four covers are to have different sized holes with diameter of 1/2, 1, 1-1/2, and 2 cm. (or 1/4, 1/2, 3/4 and 1 in.)

1 timer (0.1 sec)

1 plastic pail

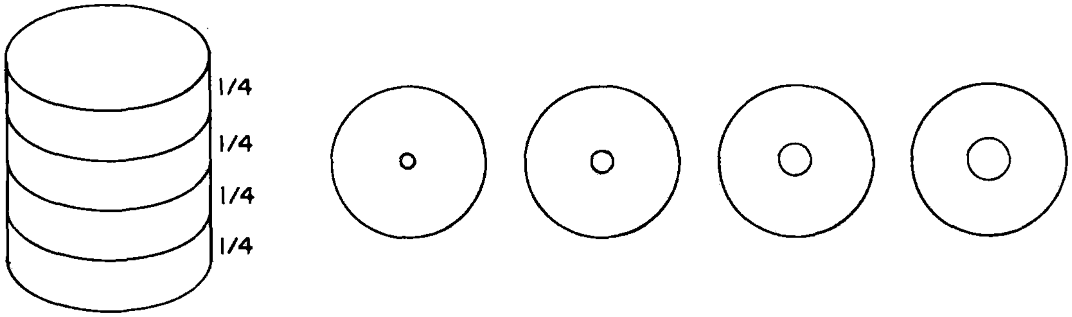


Fig. 1 - 1 Equipment for Experiment 1

NAME ______________________________ DATE ____________________

PHYSICS SECTION ______________ INSTRUCTOR'S NAME ____________________

PHYSICS LABORATORY EXPERIMENT 1 COLLECTION AND ANALYSIS OF DATA

I. PURPOSE:

II. PREDICTION:

III. DATA: The smallest diameter and depth can be used as units of measurement, for the other three dimensions are multiples of these.

Chart time in seconds as related to depth and diameter below:

Trial 1

Hole diameter	1	2	3	4	Depth
1					
2					
3					
4					

Trial 2

Hole diameter	1	2	3	4	Depth
1					
2					
3					
4					

IV. CALCULATIONS AND ANALYSIS OF DATA

Chart average time as related to depth and diameter:

Averages

Hole diameter	1	2	3	4	Depth
1					
2					
3					
4					

Graphs: A. Plot time versus depth, h, for each diameter used. Do four graphs on one sheet, using the same set of axes, connecting points in a smooth curve for each and labelling them D_1, D_2, D_3, D_4.

B. On a second sheet of graph paper, plot the time versus diameter, D, for each value of depth, h. Connect the points in a smooth curve and label the curves h_1, h_2, h_3, h_4.

C. Refer to the section on Graphing in the General Laboratory Directions. If your first graphs appear as curves, try variations to get a straight line graph, for the time-diameter relationship.

V. CONCLUSION: What type of relationship do you see between the time and diameter?

What is the relationship between time and depth?

EXPERIMENT 2

Motion at Constant Velocity

INTRODUCTION

In this experiment velocity is being treated as speed, the rate at which an object moves. It should be noted that velocity is actually a combination of speed and direction of motion. Velocity is a vector quantity and therefore has both magnitude and direction.

PROCEDURE

You will be using a recording timer to measure speed. The timers are connected to a power supply that furnishes a constant spark rate. As a tape is pulled through a timer, there will be a constant number of dots per second on the tape.

To get a record and measure of velocity, hold the end of the tape straight out from the timer and pull about a meter of tape through the timer at a speed that you consider constant, while a colleague runs the timer.

DATA

The dots on the tape represent two different types of information - position and time. Record your distance values from the starting point for each 0.1 second interval. Use the table provided giving elapsed time (t) in seconds and the distance from the starting point (x) in cm.

ANALYSIS OF DATA

Plot distance versus time. Draw a smooth curve that best fits your experimental points. Do you get a straight line? If you did not, what conclusion can you draw about your velocity? Do you know an appropriate term for this? If you did not get a straight line, select a section of your curve that approximates a straight line. Now calculate the slope of the line, $\Delta x/\Delta t$ (Δ signifies "change in"). How can this slope be defined?

Now find the average velocity for each 0.1 sec time interval. Make a new graph with time in seconds on the horizontal axis and the average velocity on the vertical axis.

EQUIPMENT LIST

1 spark timer

wax-coated recording tape

1 tape guide to allow tape to be drawn through spark gap

1 meter stick or ruler

(or 1 tape timer with tape and tape guide. Instead of a spark to mark tape, the tape timer has an electrically driven vibrator arm that has a pointed striker that strikes tape at regular intervals.)