STUDENT STUDY GUIDE FOR

PHYSICS AND THE PHYSICAL UNIVERSE 2ND ED.

JERRY B. MARION

STUDENT STUDY GUIDE

for

PHYSICS AND THE PHYSICAL UNIVERSE

Second Edition

Jerry B. Marion

University of Maryland

John Wiley & Sons, Inc.

New York London Sydney Toronto

ISBN 0-471-56921-6
Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

STUDENT STUDY GUIDE

for

PHYSICS AND THE PHYSICAL UNIVERSE

Second Edition

CONTENTS

CONTENTS

TO THE STUDENT

This Study Guide is designed to assist you in your study program for the textbook *Physics and the Physical Universe.* Each chapter of this Guide corresponds to a chapter of the text and is arranged according to the following scheme:

1. Chapter Summary
2. Summary of Important Equations
3. Multiple-Choice Questions
4. True-False Questions
5. Examples
6. Terms, Names, and Units
7. Answers
8. Readings for the Student

After completing the first reading of a chapter in the text, work through the corresponding chapter in this Guide. The first section of the Guide chapter is a brief summary of the important ideas and facts presented in the chapter. Key words and phrases have been left for you to fill in. As with all of the other questions in the Guide chapter, do not refer to the list of answers (Section 7) until you have completed the section. When the blanks have been properly filled in, this chapter summary together with the Summary of Important Ideas at the end of the chapter in the text will provide a convenient review of most of the key points that you should know about the material of the chapter.

The second section of each Guide chapter lists the various equations that are important in that chapter. These equations are primarily for reference purposes. *Do not memorize these equations.* Only very few of the basic equations are worthy of being committed to memory. Your instructor will single out those that he feels belong in this category.

Sections 3 and 4 of each Guide chapter provide extensive lists of multiple-choice and true-false questions with which you can test your comprehension of the material. Of course, to guess at the answers to these questions is of no benefit whatsoever. Mark an answer to a question only when you are confident that the answer is correct. Upon completing the section and checking the answers, note all of the questions which were unanswered or for which your answers were incorrect. Then, review the text chapter until you understand each of the points covered by these questions.

In order to demonstrate the way to apply various physical concepts (and equations) to simple problem situations, there are included in the text many worked examples. Section 5 in each Guide chapter includes several additional examples. Work through each step of these examples and be certain that you understand the *reason* for each step. It is much more important to understand the logic in the way a problem is solved than to memorize the final equation.

In Section 6 you will find a list of the various new and important terms that occur in the chapter. Scan this list and be certain that you know the meaning of each term. Mentally frame a one sentence definition or description of each term. Following this list of terms is a list of the names of persons referred to in the text as responsible for the development of some part of the material in the chapter. Associate a particular idea or experiment with each name. Finally, at the end of this section (in some chapters), there is a list of the new units for physical quantities that have been introduced in that chapter. Be certain that you know the meaning of each unit and to what quantities it applies. (Again, do *not* memorize all of the conversion factors -- only a few are sufficiently important to justify memorizing.)

Following the answer section (Section 7), there is a list of supplementary reading material on the topics in that chapter. Most of the items listed are at the elementary level and every student should be able to find several books or articles that appeal to him. (Emphasis has been placed on listing recent paperbacks; many of these can be located in any bookstore.) The first items in each list are articles from a book of readings that the author has assembled specifically to accompany the text. This collection is:

A Universe of Physics
J. B. Marion, Editor
John Wiley and Sons, Inc.
New York, New York (1970)

In using this Study Guide, remember that it is a *study* guide and not just a workbook. The summaries of the chapters, equations, and important terms provide a convenient way to review the highlights of each chapter. Take advantage of this material when studying for quizzes or examinations.


HOW HIGH ARE THE CLOUDS, LINUS?
OH, THEY'RE AT DIFFERENT HEIGHTS..SOME OF THEM ARE "FAR-AWAY HIGH" AND SOME OF THEM ARE "RIGHT-UP-THERE HIGH"
7-3
WHAT SORT OF EXPLANATION IS THAT?
SOMETIMES IT'S BEST TO KEEP THESE THINGS IN THE LANGUAGE OF THE LAYMAN!

CHAPTER 1

THE STRUCTURE AND THE LANGUAGE OF PHYSICS

1.1 Chapter Summary

Aristotelian philosophers believed that their descriptions of Nature were self-evident and therefore that it was unnecessary to test any conclusions drawn from these descriptions. This approach to science is sterile. Progress is made in science only when it is realized that *observation* and *experiment* must be coupled with *reason* and *logic* -- this we call the (1) __________ __________. The physicist seeks to understand Nature by defining and relating the quantitative aspects of simple elementary systems and then, through the use of mathematics, to develop explanations for more complex systems. There is no specific method which can be used to discover new physical laws and phenomena or to formulate successful theories; each scientist must work in his own way, always remembering the basic philosophy that underlies the scientific method. Any approach to a problem is valid as long as logic and reason are used and any conclusions are tested by (2) __________.

Physics is a *quantitative* science; the results of all experiments can be expressed in terms of (3) __________. Precision in physical measurements is important; in some instances, improvements in the precision of certain types of measurements have revealed inconsistencies with previous beliefs and have opened up entirely new areas of physics. Physics is a *precise* science but it is not an (4) ____________ science.

A *successful theory* is one that correlates a body of scientific information and permits us to understand the relationships among individual facts. Experience has shown that physical theories must have four general characteristics: (5) __________, (6) __________, (7) __________, and (8) ______________.

A *model* is a simplified mathematical construction used to approximate the behavior of an actual system and is a tool used to achieve a certain degree of understanding of the processes responsible for the behavior of complicated or as yet incompletely understood systems.

Although not often used in modern physics, the term *law* in classical physics was given to those theoretical descriptions of basic phenomena which were considered to be especially well tested. Today, almost all of the classical laws are known to have a limited range of validity.

It is convenient to express very large or very small numbers in *exponential* or (9) __________ __________ __________ notation. In this scheme, the quantity in question is expressed as a number between 0.1 and 10 multiplied by the appropriate power of 10.

Angles are measured in (10) __________ or (11) __________. A degree is (12) __________ of a complete circle. An angle of θ radians intercepts an arc of length, $S = R\theta$, of a circle of radius R. There are (13) __________ radians in a complete circle and 1 radian $\cong 57.3°$.

1.2 Summary of Important Equations

Powers of 10:

$$10^n \times 10^m = 10^{(n+m)}$$

$$10^{-n} = \frac{1}{10^n}$$

$$\frac{10^n}{10^m} = 10^{(n-m)}$$

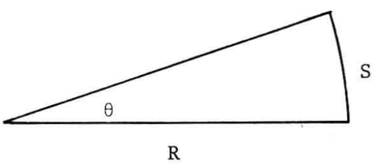
$$(10^n)^m = 10^{(n\times m)}$$

$$\sqrt[m]{N} = N^{1/m}$$

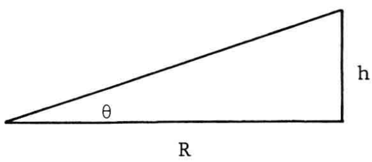
Circular measure:

$$1 \text{ rad} = \frac{360°}{2\pi} \cong 57.3°.$$

$$1° \cong 0.01745 \text{ rad}$$



$S = R\theta$



$h \cong R\theta$

1.3 Multiple-Choice Questions

1. Which of the following is correct?

   a) $1020 = 1.02 \times 10^4$, b) $367 \times 10^5 = 36.7 \times 10^7$,
   c) $0.017 = 1.7 \times 10^2$, d) $0.0068 = 6.8 \times 10^{-3}$

2. Which of the following is the largest?
   a) 0.1×10^5, b) 100^2, c) 100×10^2, d) $1/10^{-6}$.

3. Which of the following is *not* true?
   a) $10^2 \times 10^3 = 10^6$, b) $10^{-2} \times 10^2 = 1$,
   c) $10^0 = 1$, d) $(10^2)^3 = (10^3)^2$.

4. $(1/8^{1/3})^{-2} =$
   a) 1/32, b) 4, c) $4^{1/3}$, d) 1/4.

5. Which of the following is *not* equal to 2?
   a) $(2^2)^{1/2}$, b) 2×4^0, c) $(2^{1/2})^{-2}$, d) $(\sqrt{2})^3 \times (\sqrt{2})^{-1}$.

6. Which is incorrect?

   a) 1 millisecond = 10^6 nanosecond, b) 1 millimeter = 10 centimeter, c) 1 megavolt = 10^9 millivolt,
   d) 1 centimeter = 10^{-5} kilometer.

7. The results of an experiment indicate that $Y = 2.96\ X^3$.
   From this we *cannot* conclude that
   a) $Y \cong 3.0\ X^3$, b) $Y \propto X^3$, c) $Y \cong 2.958\ X^3$, d) $X \propto Y^{1/3}$.

8. An angle of $5\pi/9$ radians is how many degrees?
   a) 200, b) 100π, c) 260, d) 100.

9. A building intercepts an angle of 0.05 rad at 1200 ft.
   How high is it?
   a) 120π ft, b) 60 ft, c) 240 ft, d) 120 ft.

1.4 True-False Questions

1. Classical physics includes mechanics, thermodynamics, electromagnetism, optics, and hydrodynamics.

2. Physics is *qualitative* in character while mathematics is *quantitative* in character.

3. The physicist first examines the most elementary systems in great detail before describing the behavior of very complex systems.

4. Discoveries in physics never occur by accident.

5. In physics we can learn absolute truths.

6. Physical theories rely on experiments for their validity.

7. Advances in physics are only made by increasing the precision of measurements.

8. Physics is an *exact* science.

9. Physics develops only by means of the *scientific method.*

10. The *scientific method* prescribes in detail the approach that should be made to any scientific problem.

11. The scientific method can be used to prove that a theory is correct.

12. Physical laws may actually be inaccurate.

13. Physics is not concerned with *why* a theory is successful.

14. It is sometimes useful to think of physical quantities only in orders of magnitude.

15. Approximations are to be avoided in physics.

1.5 Example

1. Calculate $[(3 \times 10^4) \times (4 \times 10^{-6}) \div (6 \times 10^2)] +$ $+ (4.2 \times 10^{-3})$

Solution:

In order to add the two numbers, both must be expressed as the same power of 10:

$$\frac{(3 \times 10^4) \times (4 \times 10^{-6})}{6 \times 10^2} = \frac{12 \times 10^{-2}}{6 \times 10^2} = 2 \times 10^{-4}$$

$$4.2 \times 10^{-3} = \frac{42 \times 10^{-4}}{44 \times 10^{-4}}$$

So that the result is 4.4×10^{-3}.

2. Evaluate approximately: $A = \dfrac{\frac{\pi}{3} \times 6.17 \times 0.28}{(3.8 \times 4.2) + (2.1)^2}$

Solution:

We use the following approximations:

$\pi \cong 3$, so that $\pi/3 \cong 1$

$6.17 \times 0.28 \cong 6 \times 0.3 = 1.8$

$3.8 \times 4.2 \cong 4 \times 4 = 16$

$(2.1)^2 \cong (2)^2 = 4$

Therefore, we have

$$A = \frac{1 \times 1.8}{16 + 4} = \frac{1.8}{20} = 0.09$$

(A slide-rule calculation gives 0.089.)

3. From a distance of 2000 feet, a building subtends an angle of 2°. What is the height of the building?

Solution:

First, we must convert 2° into radians:

$2° = (0.01745 \text{ rad/deg}) \times (2 \text{ deg}) = 0.03490 \text{ rad}$

Then,

$h \cong R\theta = (2000 \text{ ft}) \times (0.03490) \cong 70 \text{ ft}$

1.6 Terms, Names, and Units

New and Important Terms	Names	Units
Scientific method	Galileo	Degree
Theory	Becquerel	Radian
Model	Newton	
Law	Kepler	
Exponent	Schrödinger	
Power of 10	Brahe	
Order of magnitude	Bohr	
Circular measure		

1.7 Answers

Chapter Summary

1. scientific method
2. experiment
3. numbers
4. exact
5. conciseness
6. generality
7. precision
8. capability of modification
9. powers of 10
10. degrees
11. radians
12. 1/360
13. 2π

Multiple-Choice Questions

1. d
2. d
3. a
4. b
5. c
6. b
7. c
8. d
9. b

True-False Questions

1. T
2. F
3. T
4. F
5. F
6. T
7. F
8. F
9. F
10. F
11. F
12. T
13. T
14. T
15. F

1.8 Readings for the Student

From *A Universe of Physics*:

1.1 R. P. Feynman, "The Value of Science"
1.2 V. F. Weisskopf, "The Privilege of Being a Physicist"
1.3 K. W. Ford, "The Progress of Science"
1.4 A. Einstein, "Physics and Reality"

Three excellent survey books at the popular level (and profusely illustrated) from the Time-Life series are

- D. Bergamini, *Mathematics*; Time, Inc., New York, 1963.
- R. E. Lapp, *Matter*; Time, Inc., New York, 1963.
- H. Margenau and D. Bergamini, *The Scientist*; Time, Inc., New York, 1964.

Some short (and not too demanding) books on science and society are

- J. Bronowski, *The Common Sense of Science*; Harvard University Cambridge, Mass., 1953. (Peperback edition: Random House, Vintage Books, New York.)
- J. Bronowski, *Science and Human Values*; Harper and Row, New York, New York, revised edition, 1965.
- J. B. Conant, *Science and Common Sense*; Yale University Press, New Haven, Conn., 1951.
- C. P. Snow, *The Two Cultures: And A Second Look*; Cambridge University Press, 1965.
- A. M. Weinberg, *Reflections on Big Science*; M.I.T. Press, Cambridge, Mass., 1967.

Articles on the philosophy of science (some of which are rather heavy going) will be found in

- A. B. Arons and A. M. Bork, Eds., *Science and Ideas*; Prentice-Hall, Englewood Cliffs, N. J., 1964.
- B. A. Brody and N. Capaldi, Eds., *Science: Men, Methods, Goals*; Benjamin, New York 1968.

Among the many books on the philosophy of science are

- P. W. Bridgman, *The Nature of Physical Theory*; Dover, New York, 1936.
- A. Einstein and L. Infeld, *Evolution of Physics*; Simon and Schuster, New York, 1938.
- G. de Santillana, *Origins of Scientific Thought*; University of Chicago Press, 1961.

The personal view of two outstanding physicists will be found in

- L. Leprince-Ringuet, *Atoms and Men*; University of Chicago Press, 1961.
- E. Schrödinger, *My View of the World*; Cambridge University Press, 1964.

Some interesting short biographies of scientists will be found in the article by J. Sumner Miller in *Appollo and the Universe*, edited by S. T. Butler and H. Messel (Pergamon, New York, 1968).

The quantitative aspects of physics are discussed in

F. Bitter, *Mathematical Aspects of Physics: An Introduction*; Doubleday, Garden City, N. Y., 1963.
T. Danzig, Ed., *Number, the Language of Science*; Doubleday, Garden City, N. Y., 1956.

Scientific American articles:

The entire September 1964 issue is devoted to "Mathematics".