STUDENT STUDY GUIDE WITH SELECTED SOLUTIONS

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Miami-Dade College

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FOR M. F. S.

PREFACE

This study guide was written to accompany PHYSICS: PRINCIPLES WITH APPLICATIONS, Sixth Edition, Vol. 1 by Douglas C. Giancoli. It is intended to provide additional help in understanding the basic principles covered in the textbook and add to the student's problem solving skills.

Each chapter begins with a list of Course Objectives based on the information covered in the chapter. This section is followed by a list of Key Terms and Phrases and a list of the basic mathematical equations used in the textbook. The Concept Summary section of the study guide summarizes the main topics covered in the corresponding chapter of the textbook. The concept summary section also includes the answers to three or four End-Of-Chapter questions from the textbook as well as four or five example problems similar to the type of problems found in the textbook. Each chapter of the study guide concludes with the step-by-step process to the solution to six representative problems taken from the textbook.

Because beginning physics courses emphasize problem solving, hints on problem solving skills are placed just before the representative problems taken from the textbook. The problems are solved using a programmed problem approach. A suggestion for the proper use of the programmed problem method to solving problems is included in chapter 1. The section of the textbook to which each problem corresponds is included as part of the solution.

The student should be aware that the study guide is meant to complement the textbook, not to replace the textbook as a learning tool. Because of this, it is suggested that the student carefully read the chapter in the textbook before using the study guide.

I wish to acknowledge the cooperation and assistance given by Christian Botting, Associate Editor, Physics and Astronomy, Prentice Hall, Inc. Every effort has been made to avoid errors; however, I alone have responsibility for any errors which remain and corrections and comments are most welcome.

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CONTENTS

CHAPTER 1

INTRODUCTION, MEASUREMENT, ESTIMATING

OBJECTIVES

After studying the material of this chapter, the student should be able to:

- distinguish between a scientific model and a scientific theory.
- explain why experiments are important in the testing of a theory and the improvement of a model.
- explain why uncertainty is present in all measurements and state the uncertainty after taking a measurement.
- calculate the percent uncertainty in a measurement.
- state the Système International (SI) units of mass, length, and time.
- state the metric (SI) prefixes multipliers) and use these prefixes in problem solving.
- convert English units to SI units and vice versa and use the factor-label method in problem solving.
- distinguish between basic quantities and derived quantities as well as basic units and derived units.
- express a number in power of ten notation and use power of ten notation in problem solving.
- explain what is meant by an order-of-magnitude estimate and use order-of-magnitude estimates in problems involving rapid estimating.

KEY TERMS AND PHRASES

science attempts to explain natural phenomena that can be detected with our senses or by instruments designed to extend our senses, e.g., a telescope.

physics is the branch of science that deals with natural laws and processes, and the states and properties of matter and energy.

matter refers to any object that has substance and occupies space.

energy is a measure of the ability to do work. Energy takes a number of forms, such as mechanical energy, electromagnetic energy, heat energy, and nuclear energy.

model, as used in physics, is an analogy or mental image used to explain physical phenomena.

scientific theory, as used in physics, is a plausible principle offered to explain physical phenomenon. A theory leads to predictions that can then be tested by experiment to see if there is agreement with the phenomenon.

scientific law is applied to certain statements that are found to be valid over a large range of observed phenomena. An example of a scientific law is the law of universal gravitation.

significant figures in a measurement include the figures that are certain plus the first doubtful digit.

Système International (SI) system of measurement is the system of measurement established by the French Academy of Science. For example, in SI units, the unit of length is the meter (m), time is second (s), and mass is kilogram (kg).

order-of-magnitude is a rough estimate of the value of a quantity. This estimate usually contains one significant figure and the associated power of ten. For example, one often hears the world population given to the nearest billion.

CONCEPT SUMMARY

Science and Creativity

Science attempts to explain natural phenomena that can be detected with our senses or by instruments designed to extend our senses, e.g., a telescope. Science is a creative endeavor that resembles other creative activities of the human mind, e.g., art and music. **Physics** is the branch of science that deals with natural laws and processes, and the states and properties of **matter** and **energy**.

To explain a particular natural phenomenon, a scientist constructs a **model** that leads to a **theory** designed to explain the phenomenon. The theory leads to predictions that can then be tested by experiment to see if there is agreement with the phenomenon.

In science, the term **law** is applied to certain statements that are found to be valid over a large range of observed phenomena. An example of a scientific law is the law of universal gravitation. Scientific laws are descriptive in that they "describe how nature does behave" as compared to a traffic law which tells us how we should behave.

Measurement and Uncertainty

Every measurement is limited in terms of accuracy. This limitation is associated with the measuring instrument and as stated in the textbook human "inability to read the instrument beyond some fraction of the smallest division shown." Because of this, it is common to include the estimated uncertainty associated with a scientific measurement. For example, the width of a table might be 85.10 ± 0.01 inches. The ± 0.01 inches is the uncertainty in the measurement. The percent uncertainty is the ratio of the uncertainty to the measured value, for example, $0.01/85.10 \times 100\% = 0.01\%$.

The number of significant figures in a measurement includes the figures that are certain and the first doubtful digit. In the example of the table, which is 85.10 ± 0.01 inches long, there are four significant figures. The 8, 5, and 1 are certain and the 0 is the doubtful digit. Calculations must follow the rules for significant figures. The final answer must have the same number of significant figures as the least significant factor used in the calculation.

TEXTBOOK QUESTION 4. What is wrong with this road sign: Memphis 7 mi (11.263 km)?

ANSWER: The road sign states the distance in miles to one significant figure while it states the distance in kilometers to 5 significant figures. The same number of significant figures should be used whether the distance is given in miles or kilometers.

HOW TO USE THE PROGRAMMED PROBLEM APPROACH TO PROBLEM SOLVING

The example problems and problems from the textbook follow a programmed problem method of solving problems. The problems are arranged in a step-by-step process that leads to the solution. The student should be aware that there is often more than one way to solve a problem and at times an alternate solution will be included.

Each part of the problem is broken down into individual steps. The steps are represented by individual frames that are divided into a left side where a question is posed and a right side where the answer is located. Each step is designated with a letter and number. For example, Part b. Step 2. indicates that this frame is the second step to the solution of Part b of the problem. The right side should be covered with a blank sheet of paper on which you should attempt to answer the question. After completing your answer, uncover the right frame and check your work. The individual frames are separated by a line that extends across the page and the end of the problem is indicated by a thick black line.

EXAMPLE PROBLEM 1. Determine the percent uncertainty in the area of a square that is 6.08 ± 0.01 m on a side.

Part a. Step 1. Determine the area if each side is 2.54 m in length.	Solution: (Section 1-4) area = 6.08 m x 6.08 m = 37.0 m^2 Note: using a calculator, the product is 36.9664. However, there are only three significant figures in each factor and the answer must be rounded off to three significant figures.
Part a. Step 2. Determine the maximum possible area.	maximum length = 6.08 m + 0.01 m = 6.09 m maximum area = 6.09 m x 6.09 m = 37.1 m^2
Part a. Step 3. Determine the minimum possible area.	minimum length = 6.08 m - 0.01 m = 6.07 m minimum area = 6.07 m x 6.07 m = 36.9 m^2
Part a. Step 4. Write the area with the associated uncertainty.	The maximum area is greater than the area by 0.10 m^2 and the minimum area is less by 0.10 m^2. The area can now be written as area = 37.0 ± 0.10 m^2

Part a. Step 5. Determine the percent uncertainty.	percent uncertainty = $(0.10\ m^2)/(37.0\ m^2) \times 100\%$ Percent uncertainty = 0.27%

Système International (SI) System of Measurement

The measurement of any quantity is made relative to a particular standard or unit. The system used almost exclusively in this book is the Système International (SI system of measurement). In SI units, the unit of length is the meter (m), time is second (s), and mass is kilogram (kg). Length, time, mass, electric current, temperature, amount of substance, and luminous intensity are base quantities. The base unit associated with electric current is the ampere, temperature is degrees kelvin, amount of substance is the mole, and luminous intensity is candela. All other quantities can be derived from the base quantities. The units associated with these derived quantities are called derived units. An example of a derived quantity is force and the unit of force is the newton (N) where 1 N = 1 kg m/s^2.

TEXTBOOK QUESTION 1. What are the merits and drawbacks of using a person's foot as a standard? Consider both (a) a particular person's foot and (b) any person's foot. Keep in mind that it is advantageous that fundamental standards be accessible (easy to compare to), invariable (do not change), indestructible, and reproducible.

ANSWER: For a standard to be useful it must be accessible, invariable, indestructible, and reproducible everywhere. The problem that is now faced is that while the criteria invariable and indestructible might be met, the fundamental standards may not be accessible or easily understood by the average person.

For example, from 1893 to 1960 the United States standard for length was the distance between two scratches on a metal bar made of a platinum-iridium alloy. This standard meets the criteria plus has the advantage of being easily understandable to the common person. Since 1960, the meter has been defined as 1,650,763.73 times the wavelength of the red-orange spectral line of the krypton-86 isotope. This standard meets the criteria but is less accessible and certainly less understandable to the average person.

Whether the standard is the foot of a particular person or any person's foot, the major drawback is that the length of the foot tends to change with time and is not reproducible. Also, the standard is lost and therefore destructible when the person dies. The only advantage is that a foot is accessible and can be easily used to give a rough estimate of short distances.

EXAMPLE PROBLEM 2. Express the height of a person 5'4" tall in a) centimeters and b) meters. Express your answer to the correct number of significant figures.

Part a. Step 1. Convert 5'4" to inches.	Solution: (Section 1-6) (5 feet)(12 inches/1 feet) + 4 inches = 64 inches

Part a. Step 2.	(64 inches)(2.54 cm/1 inch) = 162.6 cm
Express the person's height in centimeters.	64 inches has only two significant figures; therefore, 162.6 cm must be reduced to two significant figures. The person's height to the correct number of significant figures is 160 cm.
Part b. Step 1.	(160 cm)(1.00 m/100 cm) = 1.60 m
Express the height in meters (m).	The answer must be reduced to two significant figures. The person's height is 1.6 m.

EXAMPLE PROBLEM 3. The equatorial diameter of the Earth given to three significant figures is 7930 miles. Express the diameter in a) meters (m) and b) kilometers (km) and use power of ten notation in your final answer.

Part a. Step 1.	Solution: (Section 1-6)
Express the diameter in meters (m). Note: 1 mile = 1609 m	Using a calculator, the diameter is (7930 mi)(1609 m/1 mi) = 12,759,370 m The diameter of the Earth is given to three significant figures. It is necessary to round off the answer to three significant figures. Therefore, the diameter = 12,800,000 m The diameter in power of ten notation = 1.28×10^7 m
Part b. Step 1.	1.000 km = 1000 m
Determine the diameter in km.	$(1.28 \times 10^7$ m)(1.000 km/1000 m) = 1.28×10^4 km

Order of Magnitude: Rapid Estimating

It is sometimes useful to give a rough estimate of the value of a quantity. This estimate is called the **order-of-magnitude** and this number contains one significant figure and the associated power of ten. For example, one often hears the world population given to the nearest billion.

An example of rapid estimating would be the number of people watching a parade. Suppose the parade route is 1 mile long with people lined up 5 deep on each side of the street. Each person taking up an average of 2 feet of space.

(1 person/2 feet) x (5280 feet/1 mile) x 2 sides of street x (5 people/1 space) $\approx$ 30,000 people

The symbol $\approx$ means that the measurement is an approximation. For this problem, the actual size of the crowd could easily be $\pm$3000 to 5000 people.

PROBLEM SOLVING SKILLS

For problems involving percent uncertainty in area or volume and the linear dimensions are given:

1. Determine the maximum and minimum possible values for the area or volume.
2. Determine the uncertainty in the measurement.
3. Divide the uncertainty by the measurement and multiply by 100%. If the problem involves a linear measurement, then steps 1 and 2 are not necessary to solve the problem.

For problems involving conversion of English units to SI units or vice versa.

1. List the quantity given and, if necessary, express it in one unit. For example, 1 min and 10 seconds = 70 seconds.
2. Use the unit rule, also known as the factor-label method, to solve the problem.
3. Where appropriate, use power of ten notation. Make sure to follow the rules for multiplication, division, addition, and subtraction of quantities which are expressed as powers of ten.
4. Apply the rules of significant figures in solving the problem. Remember that the answer must have the same number of significant figures as the least significant factor.

SOLUTIONS TO SELECTED TEXTBOOK PROBLEMS

TEXTBOOK PROBLEM 1. The age of the universe is thought to be about 14 billion years. Assuming two significant figures, write this in powers of ten in (a) years, (b) seconds.

Part a. Step 1. Use the factor-label method to convert to power of ten.	Solution: (Section 1-4) 1 billion = 10^9 (14 billion years)[(10^9 years)/(1 billion)] = 1.4×10^{10} years
Part a. Step 2. Use the factor-label method to convert years to seconds (s).	(1.4×10^{10} yr)[(365.25 days)/(1 yr)][(24 h)/(1 day)][(3600 s)/(1 hour)] = 4.4×10^{17} s

TEXTBOOK PROBLEM 6. What is the percent uncertainty in the measurement 3.76 ± 0.25 m?

Part a. Step 1. Determine the percent uncertainty.	Solution: (Section 1-4) The percent uncertainty is the ratio of the uncertainty to the measured value multiplied by 100 %. Therefore, (0.25 m)/(3.76 m) x 100% = 6.6 %

TEXTBOOK PROBLEM 15. The Sun, on average, is 93 million miles from the Earth. How many meters is this? Express (a) using powers of ten, and (b) using a metric prefix.

Part a. Step 1. Use the factor-label method to convert miles to meters. 1609 m = 1 mile	Solution: (Section 1-6) (93 million miles)[(10^6 miles)/(1 million miles)][(1609 m)/(1 mile)] = 1.5×10^{11} m
Part b. Step 1. Express the answer using a metric prefix.	From Table 1-4 the prefix giga, abbreviated G, represents 10^9. Therefore, (1.5×10^{11} m)[(1 G)/(10^9)] = 1.5×10^2 Gm or 150 Gm

TEXTBOOK PROBLEM 23. The diameter of the Moon is 3480 km. What is the surface area of the Moon. (b) How many times larger is the surface area of the Earth?

Part a. Step 1. Determine the is surface area of the Moon.	Solution: (Sections 1-5 and 1-6) Assume that the Moon is a sphere. The formula for the surface area (A) of a sphere is $A = 4\pi r^2$ where r = the radius of the sphere. r = ½ diameter = ½ (3480 km) = 1740 km $A_{Moon} = 4\pi (1740 \text{ km})^2 = 3.80 \times 10^7 \text{ km}^2$
Part b. Step 1. Determine the land surface area of the Earth.	Based on information provided in the inside cover of the textbook, the radius of the Earth is 6380 km. $A_{Earth} = 4\pi (6380 \text{ km})^2 = 5.11 \times 10^8 \text{ km}^2$
Part b. Step 2. Determine the ratio the surface areas.	ratio of areas = $(5.11 \times 10^8 \text{ km}^2)/(3.80 \times 10^7 \text{ km}^2) \approx 13.4$ The Earth has approximately 13.4 times more surface area than the of Moon.

TEXTBOOK PROBLEM 27. Estimate how long it would take one person to mow a football field using an ordinary home lawn mower (Fig. 1-13). Assume that the mower moves with a 1 km/h speed, and has a 0.5 m width.

Part a. Step 1. Determine the lawn mower's speed in m/s.	Solution: (Section 1-7) (1 km/h) x (1000 m/km) x (1h/3600 s) $\approx$ 0.28 m/s

Part a. Step 2. Estimate the area cut by the mower each second.	The area cut each second equals the forward speed times the length of the blade. $(0.28\ m/s)(0.5\ m) \approx 0.14\ m^2/s$
Part a. Step 3. Estimate the area of a football field.	Length of the football field = 100 yards + 10 yards per end zone Length = 120 yards ≈ 110 meters Width of the football field is 53.3 yards ≈ 49 m Area = length x width = 110 m x 49 m ≈ 5400 m^2
Part a. Step 4. Estimate the time required to mow the field.	time = (area of football field) ÷ (area cut each second) time = $(5400\ m^2) \div (0.14\ m^2/s) \approx 39000\ s \approx 11$ hours Note: this is a very rough estimate. The estimate assumes that the person continues to mow at a constant rate for the entire time.

TEXTBOOK PROBLEM 51. The diameter of the Moon is 3480 km. What is the volume of the Moon? How many Moons would be needed to create a volume equal to the volume of the Earth?

Part a. Step 1. Determine the volume of the Moon. Assume that the Moon is a perfect sphere.	Solution: (Section 1-7) $V_{Moon} = 4/3\ \pi\ R^3$ where $R_{Moon} = ½(3480\ km) = 1740\ km$ $= 4/3\ \pi\ [(1740\ km)(1000\ m/1\ km)]^3$ $V_{Moon} = 2.20 \times 10^{19}\ m^3$
Part a. Step 2. Determine the ratio of the Earth's volume to the Moon's volume. Note: the radius of the Earth is 6380 km.	$V_{Earth}/V_{Moon} = (4/3\ \pi\ R_E^3)/(4/3\ \pi\ R_M^3)$ Note: both 4/3 and π cancel. $= R_E^3/R_M^3$ $= (6380\ km)^3/(1740\ km)^3$ $V_{Earth}/V_{Moon} \approx 49.3$