


NINTH EDITION



Study Guide to Accompany  
**The Physical  
Universe**



Steven D. Carey  
Arthur Beiser

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Steven D. Carey  
*University of Mobile*

Arthur Beiser



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Study Guide to Accompany Krauskopf/Beiser: THE PHYSICAL UNIVERSE,  
NINTH EDITION

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Vice president and editorial director: *Kevin T. Kane*  
Publisher: *JP Lenney*  
Developmental editor: *Colleen Fitzpatrick*  
Marketing manager: *Mary K. Kittell*  
Senior project manager: *Marilyn Rothenberger*  
Senior production supervisor: *Mary E. Haas*  
Designer manager: *Stuart D. Paterson*  
Typeface: *10/12 Times Roman*  
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## PREFACE

This study guide accompanies *The Physical Universe*, ninth edition, by Krauskopf and Beiser. Each of the study guide's chapters is keyed to its counterpart in the text and contains a chapter summary, a sentence outline of the chapter, and additional review questions and explanatory materials designed to enhance the student's understanding of the key terms and main concepts presented in *The Physical Universe*.

This study guide differs from most others in several respects. Key terms, instead of appearing as a simple list are defined in the chapter outline and are identified by boldface type. Representative example problems, selected from those in the text, are solved in a step-by-step fashion so that students with limited backgrounds in mathematics can enhance their problem-solving skills by seeing how the solutions are derived. A special section containing inexpensive and easy-to-do physical science experiments has been added for those students majoring in elementary or early childhood education.

Many people assisted in the preparation of this study guide. Arthur Beiser reviewed the manuscript and offered valuable criticisms and suggestions. Colleen Fitzpatrick of WCB/ McGraw-Hill, Inc., provided much needed encouragement and support. To these individuals, anonymous reviewers, colleagues, and family, I am sincerely grateful.

Steven D. Carey  
*Department of Natural Sciences*  
*University of Mobile*

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# 1

## THE

## SCIENTIFIC

## METHOD

### CHAPTER CONTENTS

#### HOW SCIENTISTS STUDY NATURE

- 1-1 The Scientific Method
- 1-2 Why Science Is Successful

#### THE SOLAR SYSTEM

- 1-3 A Survey of the Sky
- 1-4 The Ptolemaic System
- 1-5 The Copernican System
- 1-6 Kepler's Laws
- 1-7 Why Copernicus Was Right

#### UNIVERSAL GRAVITATION

- 1-8 What Is Gravity?
- 1-9 Why the Earth Is Round
- 1-10 The Tides
- 1-11 The Discovery of Neptune

### CHAPTER GOALS

When you have completed Chapter 1 you should be able to:

1. Outline the scientific method.
2. Explain why the scientific method has been more successful than other approaches to understanding the universe.
3. Distinguish between a law and a theory.
4. Discuss the role of a model in formulating a scientific theory.
5. Give the reason why Polaris is the heavenly body that remains most nearly stationary in the sky.
6. Define constellation.
7. Tell how to distinguish planets from stars by observations of the night sky made several weeks or months apart.
8. Compare how the ptolemaic and copernican systems account for the observed motions of the sun, moon, planets, and stars across the sky.
9. Explain the significance of Kepler's laws.
10. State why the copernican system is considered correct.
11. Define day and year.
12. Define fundamental force.
13. Explain why the earth is round but not a perfect sphere.
14. Explain the origin of tides.
15. Explain in terms of the scientific method why the discovery of Neptune was so important in confirming the law of gravity.

## CHAPTER SUMMARY

This chapter introduces the **scientific method**, the process scientists use to interpret the physical universe. Science is a living body of knowledge whose **laws** and **theories** are subject to constant test and change. Although science can never arrive at an "ultimate truth," it has nevertheless successfully explained the natural world and has improved the quality of life. The scientific method is illustrated by the acceptance of the **copernican model** of the universe over the ancient Greek **ptolemaic model**. In turn, this advance led to Kepler's discovery of the **laws of planetary motion** and Newton's discovery of the **law of gravity**. Gravity is one of four **fundamental forces**. The law of gravity has been verified by accounting for the occurrence of the tides, the shape of the earth, and by its successful application in the discovery of the planet Neptune.

## CHAPTER OUTLINE

### 1-1. The Scientific Method

- A. The **scientific method** consists of four steps:
  - 1. **Formulation of a problem**
  - 2. **Observation and experiment**
  - 3. **Interpretation**
  - 4. **Testing the interpretation**
- B. An initial scientific interpretation is called the **hypothesis**.
- C. A **law** describes a relationship or regularity between naturally occurring phenomena.
- D. A **theory** explains why a phenomenon or a set of phenomena occurs.
- E. Scientists often use **models** to simplify complex situations.
- F. Newton chose an oval called an **ellipse** as a model of the earth's orbit.

### 1-2. Why Science Is Successful

- A. A scientific law or theory, if refuted by contrary evidence, must be modified or discarded.
- B. The work of scientists is open to review, test, and change.
- C. Science has provided an understanding of the natural world and a sophisticated technology.
- D. Scientific laws and theories are not accepted as "absolute truth" and therefore differ from belief systems.

### 1-3. A Survey of the Sky

- A. To an observer north of the equator, the position of the North Star, or **Polaris**, changes very little, and the whole nighttime sky appears to revolve around Polaris.

- B. The **constellations** are easily recognized groups of stars and are useful as labels for regions of the sky.
- C. The **planets** visible to the naked eye (Mercury, Venus, Mars, Jupiter, and Saturn) appear to drift in a generally eastward motion relative to the stars; however, each planet at times appears to head westward briefly, and its path across the sky resembles a series of loops.

#### 1-4. The Ptolemaic System

- A. Ptolemy of Alexandria (2nd century A.D.) described the universe in the *Almagest*.
  - 1. The earth is the center of the universe.
  - 2. The sun, stars, and planets revolve around the earth.
  - 3. The orbits of the planets are circular.
- B. According to Ptolemy, the planets as they orbit the earth travel in a series of loops (epicycles).
- C. The **ptolemaic system** had the components of a valid theory:
  - 1. It was based on observation.
  - 2. It apparently accounted for known celestial motions.
  - 3. It made predictions that could be tested.

#### 1-5. The Copernican System

- A. The ptolemaic system failed to make accurate predictions of planetary positions.
- B. Nicholas Copernicus (1473-1543) developed a new theory of the universe:
  - 1. The earth and planets follow circular orbits around the sun.
  - 2. The earth rotates on its axis once every 24 hours.
  - 3. The earth's rotation explains the daily rising and setting of celestial bodies.
  - 4. Irregular movements of the planets are a result of the combination of their motions around the sun and the change in position of the earth in its orbit.
- C. The **copernican system** was attacked by religious leaders and by other supporters of the ptolemaic system.

#### 1-6. Kepler's Laws

- A. Johannes Kepler (1571-1630), using Tycho Brahe's improved measurements of planetary motion, found fault with the copernican system.
- B. Kepler's calculations resulted in the discovery of three laws of planetary motion:
  - 1. The paths of the planets around the sun are ellipses.
  - 2. A planet moves so that its radius vector sweeps out equal areas in equal times.

3. The ratio between the square of the time needed by a planet to make a revolution around the sun and the cube of its average distance from the sun is the same for all the planets.
- C. Kepler's laws agreed with past observations of planetary positions and made accurate predictions of future planetary movements.

### 1-7. Why Copernicus Was Right

- A. There is direct evidence that the earth rotates and revolves around the sun.
- B. There is direct evidence for the motions of the moon and the other planets.

### 1-8. What Is Gravity?

- A. Isaac Newton's (1642-1727) discovery of the law of gravity was dependent upon Copernicus's model of the solar system.
- B. Gravity is a **fundamental force**.
  1. A fundamental force cannot be explained in terms of any other force.
  2. There are four fundamental forces:
    - a. Gravitational
    - b. Electromagnetic
    - c. Weak
    - d. Strong
- C. Gravity is thought to be a universal force because:
  1. Observed star systems and galaxies behave as if influenced by gravity.
  2. Matter appears to be the same throughout the universe; therefore, gravitational attraction must also be universal.
  3. There is no evidence that gravity is not universal.

### 1-9. Why the Earth Is Round

- A. The theory of gravity accounts for the earth's shape; the earth is round because gravity squeezes it into a spherical shape.
- B. The earth is not a perfect sphere because its spinning motion causes it to bulge slightly at the equator and flatten slightly at the poles.

### 1-10. The Tides

- A. The law of gravity successfully explains the occurrence of the tides.
- B. The earth's tides are the result of the gravitational attraction of the moon and the sun.
- C. Coastal areas experience two high tides and two low tides each day.

- D. The relative positions of the earth, sun, and moon produce different tides.
1. Unusually high (and low) **spring tides** occur bimonthly when the moon and sun are aligned with the earth.
  2. Weak **neap tides** occur bimonthly when the sun and moon pull at right angles to each other in regard to earth.

### 1-11. The Discovery of Neptune

- A. Discrepancies in the predicted orbit of Uranus led to two hypotheses:
1. The law of gravity is wrong.
  2. An unknown body is exerting a gravitational pull on Uranus.
- B. Calculations based on the law of gravity predicted the position of an unknown body.
- C. The prediction was tested, resulting in the discovery of Neptune.

### KEY TERMS AND CONCEPTS

The questions in this section will help you review the key terms and concepts from Chapter 1.

#### Short Answer

Each statement below represents a specific step in the scientific method. Decide which one of the four steps--**formulating a problem, observation and experiment, interpretation, or testing the interpretation**--applies to the statement and write the name of the step in the space below the statement.

1. Isaac Newton wonders if the force holding the planets in orbit around the sun is the same force that pulls objects to the earth's surface.
2. Johannes Kepler calculates planetary motion from the data of Tycho Brahe.
3. Albert Einstein's prediction that light is affected by gravity is verified by experiment.
4. Ptolemy of Alexandria describes a model of the universe with the earth stationary at its center and with the sun revolving around the earth.
5. A scientist asks what the relationship is between the moon and the earth's tides.

6

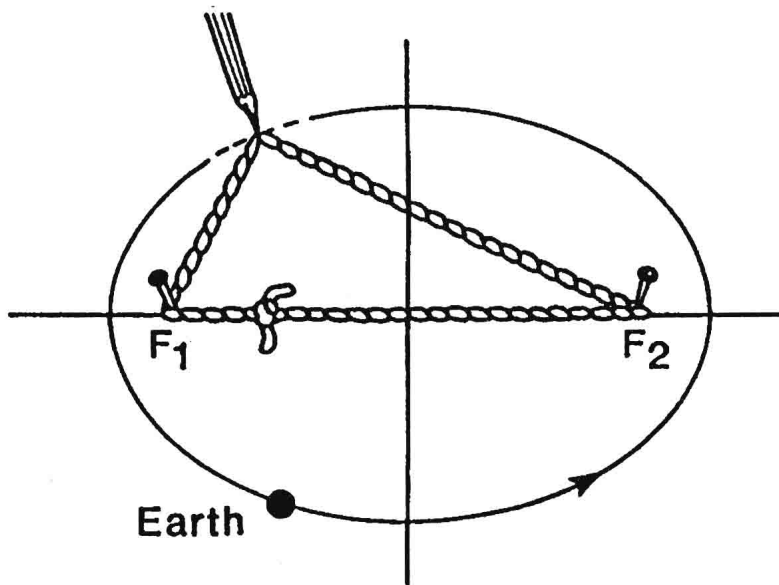
6. Tycho Brahe's observatory was able to determine celestial angles to better than 1/100 of a degree.
7. Urbain Leverrier of France and John Couch Adams of England propose that an unseen and unknown celestial body is responsible for the observed discrepancies in the orbit of Uranus and calculate the unknown body's position.
8. Johann Gottfried Galle, using the prediction made by Leverrier, discovers the planet Neptune.
9. Nicolaus Copernicus asks if the planets move around the sun rather than around the earth.
10. Copernicus proposes that the earth rotates once on its axis every 24 hours.

### Multiple Choice

Circle the best answer for each of the following questions.

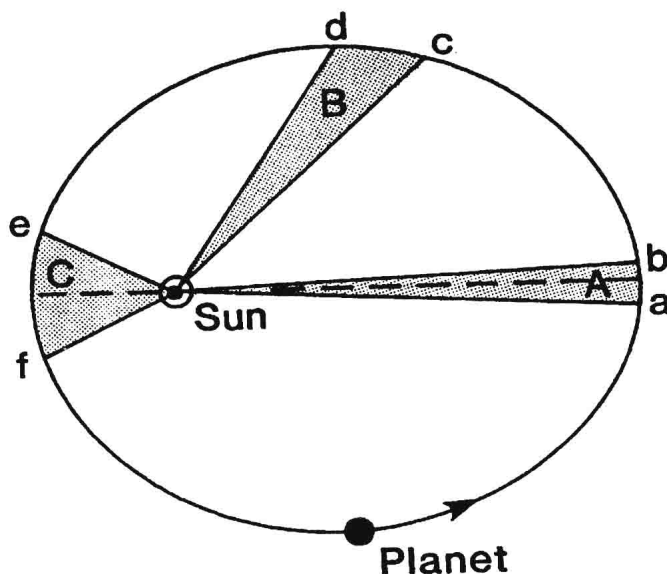
1. A scientific law
  - a. is seldom based upon experimental evidence since it can never be considered to be absolutely true
  - b. usually states a regularity or relationship that describes how nature behaves in a certain specific way
  - c. explains why certain phenomena in nature take place
  - d. is known to be true beyond a shadow of a doubt
2. The ptolemaic system fulfilled the requirements of a scientific theory because
  - a. its explanations of celestial motions, based on observations, resulted in testable predictions
  - b. it was presented openly for public inspection when included in Ptolemy's *Almagest*
  - c. it was believed to represent an accurate view of the universe and solar system by religious leaders and learned scholars of the time
  - d. it provided a "common sense" explanation concerning the observed motions of heavenly bodies

3. Which statement best characterizes the nature of science?
  - a. the laws and theories of science are based on belief and speculation
  - b. science is a living body of knowledge, not a set of unchanging ideas
  - c. science has done a poor job of explaining physical phenomena and has failed to improve the quality of human life
  - d. science is superior to other aspects of human culture such as religion, art, and music
4. The shape of the earth could best be described as resembling that of a(n)
  - a. egg
  - b. top
  - c. watermelon
  - d. grapefruit
5. Newton's discovery of the law of gravity was dependent upon
  - a. the discovery of the planet Neptune
  - b. an understanding of the shape of the earth
  - c. the development of the copernican system of the solar system
  - d. the law that states what goes up must come down
6. The time it takes a planet to make one complete trip around the sun is called the planet's
  - a. revolution
  - b. orbit
  - c. rotation
  - d. period
7. The modern version of the copernican system is considered to be correct because
  - a. most people believe that the copernican system is correct, and the majority viewpoint rules
  - b. predictions of planetary motions based on the copernican system proved to be correct
  - c. there is direct evidence that the earth rotates and the planets revolve around the sun
  - d. a committee of scientists has certified that the copernican system is correct
8. When observable evidence does not agree with a scientific theory
  - a. the truthfulness of the evidence must be questioned since a theory is never wrong
  - b. the evidence is ignored and the theory remains valid
  - c. the theory is reduced in status to a hypothesis
  - d. the theory must be modified or discarded
9. Spring tides
  - a. occur only in the spring
  - b. occur when the sun and moon are in line with the earth
  - c. have a low range between high and low water
  - d. occur when the sun and moon are  $90^\circ$  apart relative to the earth



Refer to the above drawing to answer multiple choice questions 10-12.

10. The points corresponding to the positions of the tacks are called
  - a. epicycles
  - b. focuses
  - c. planets
  - d. orbits
11. The sun would occupy a position
  - a. at either point  $F_1$  or  $F_2$
  - b. at the center of the ellipse
  - c. at the pencil
  - d. somewhere on the circumference of the ellipse
12. The drawing is a visual representation of
  - a. Newton's law of gravity
  - b. Kepler's first law of planetary motion
  - c. Kepler's second law of planetary motion
  - d. Kepler's third law of planetary motion



Refer to the above drawing to answer multiple choice questions 13-15. Let the amount of time it takes the planet to travel the distance from a to b, from c to d, and from e to f to be the same.

13. Section C is
  - a. greater in area than section A
  - b. greater in area than section B
  - c. lesser in area than either section A or B
  - d. the same in area as section A or B
  
14. The planet would be traveling the fastest along that portion of its orbit represented by the distance between the letters
  - a. a and b
  - b. c and d
  - c. e and f
  - d. none of the answers is correct because the planet's speed remains constant along its orbit
  
15. If the average orbit radius of the planet is increased, the period of the planet will
  - a. decrease
  - b. increase
  - c. remain unchanged
  - d. decrease or increase depending on the mass of the planet

**True or False**

Decide whether each statement is true or false. If false, either briefly state why it is false or correct the statement to make it true. The first question has been completed as an example.

- FALSE      1.      The study of physical science includes topics in the world of human events such as politics and economics.
- Physical science investigates the world of nature and covers topics in the fields of physics, chemistry, geology, and astronomy.
- \_\_\_\_\_ 2.      Scientists study nature by using both direct and indirect methods.
- \_\_\_\_\_ 3.      The laws and theories of science represent the ultimate truth about our physical universe.
- \_\_\_\_\_ 4.      According to Kepler's third law, the speed that a planet travels in its orbit around the sun depends upon the planet's mass.
- \_\_\_\_\_ 5.      Kepler's laws of planetary motion are explained by Newton's discovery of the law of gravity.
- \_\_\_\_\_ 6.      When first proposed, a scientific interpretation is usually called a theory.
- \_\_\_\_\_ 7.      Astrology has been used to make consistently accurate predictions about the future.

**Fill in the Blank**

1.      An imaginary line joining a planet with the sun is known as its \_\_\_\_\_ vector.
2.      \_\_\_\_\_ are groups of stars named after objects, animals, people, or mythological beings.

3. \_\_\_\_\_, or the North Star, appears to move very little while the whole nighttime sky appears to revolve around it.
4. In the copernican system, the orbits of the planets are \_\_\_\_\_ in shape.
5. A \_\_\_\_\_ is any circle on the earth's surface whose center is the earth's center.
6. The \_\_\_\_\_ is a great circle midway between the north and south poles.
7. A \_\_\_\_\_ is a great circle that passes through both the north and south poles.
8. The \_\_\_\_\_ of a point on the earth's surface is the angular distance between a meridian through this point and the prime meridian.
9. The \_\_\_\_\_ of a place on the earth's surface is the angular distance of the place north or south of the equator.
10. The \_\_\_\_\_ is a unit of speed equal to 1 nautical mile per hour.

### Matching

Match the name of the person on the left with the description on the right.

- |          |                        |    |  |
|----------|------------------------|----|--|
| 1. _____ | Johann Gottfried Galle | a. | believed the earth was stationary at the center of the universe  |
| 2. _____ | Tycho Brahe            | b. | discovered the law of gravity  |
| 3. _____ | Isaac Newton           | c. | discovered the planet Neptune  |
| 4. _____ | Ptolemy of Alexandria  | d. | proposed that the earth rotates on its axis and, along with the other planets, revolves around the sun |
| 5. _____ | Johannes Kepler        | e. | Danish astronomer whose measurements of planetary motion resulted in revision of the copernican system |
| 6. _____ | Nicolaus Copernicus    | f. | discovered the three laws of planetary motion  |

**ANSWER KEY****Short Answer**

- |                               |                               |
|-------------------------------|-------------------------------|
| 1. Formulating a Problem      | 6. Experiment and Observation |
| 2. Experiment and Observation | 7. Interpretation             |
| 3. Testing the Interpretation | 8. Testing the Interpretation |
| 4. Interpretation             | 9. Formulating a Problem      |
| 5. Formulating a Problem      | 10. Interpretation            |

**Multiple Choice**

1. b   2. a   3. b   4. d   5. c   6. d   7. c   8. d   9. b   10. b   11. a   12. b   13. d  
14. c   15. b

**True or False**

- False. See explanatory notes given in the example.
- True
- False. There are no ultimate truths in science; scientific laws and theories are valid only as long as no contrary evidence comes to light.
- False. The speed that a planet travels in its orbit around the sun depends upon its distance from the sun.
- True
- False. When first proposed, a scientific interpretation is usually called a hypothesis.
- False. There is no evidence that astrology can predict the future.

**Fill in the Blank**

- |                   |              |
|-------------------|--------------|
| 1. radius         | 6. equator   |
| 2. constellations | 7. meridian  |
| 3. Polaris        | 8. longitude |
| 4. circular       | 9. latitude  |
| 5. great circle   | 10. knot     |

**Matching**

1. c   2. e   3. b   4. a   5. f   6. d