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The Physical Universe

Eleventh Edition

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Arthur Beiser



Higher Education

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THE PHYSICAL UNIVERSE, ELEVENTH EDITION

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2 3 4 5 6 7 8 9 0 QPD/QPD 0 9 8 7 6

ISBN-13: 978-0-07-250979-3

ISBN-10: 0-07-250979-1

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Compositor: *The GTS Companies/York, PA Campus*

Typeface: *10/12 New Aster*

Printer: *Quebecor World Dubuque, IA*

The credits section for this book begins on page C-1 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Krauskopf, Konrad Bates, 1910–2003

The physical universe / Konrad B. Krauskopf, Arthur Beiser.—11th ed.
p. cm.

Includes index.

ISBN 0-07-250979-1 (hard copy : alk. paper)

1. Physical sciences. I. Beiser, Arthur. II. Title.

Q161.2.K7 2006

500.2—dc22

2004011475










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Table 15-2 Geologic Time. (The Earth Came into Existence About 4600 Million Years Ago)

Millions of Years Ago	Era	Period	Epoch	Duration, Million Years	The Biologic Record	The Geologic Record
65	Cenozoic	Quaternary	Holocene	0.01	Humans become dominant	Ice Age
225			Pleistocene	2.5	Rise of humans; large mammals abundant	
570		Tertiary	Pliocene	4.5	Flowering plants abundant	Atlantic Ocean widens Alps and Himalayas form; Red Sea opens India collides with Asia Australia separates from Antarctica Norwegian Sea and Baffin Bay open
			Miocene	19	Grasses abundant; rapid spread of grazing mammals	
	Oligocene		12	Apes and elephants appear		
	Eocene		16	Primitive horses, camels, rhinoceroses		
4,000	Mesozoic	Paleocene	11	First primates	Laurasia and Gondwana begin to break up Laurasia separates from Gondwana Pangaea complete	
		Cretaceous	71	Spread of flowering plants; dinosaurs die out		
		Jurassic	54	First birds; dinosaurs at their peak		
		Triassic	35	Dinosaurs and first mammals appear		
		Permian	55	Rise of reptiles; large insects abundant		
		Carboniferous	65	Large nonflowering plants in enormous swamps; large amphibians; extensive forests; sharks abundant		
		Devonian	50	First forests and amphibians; fish abundant		
		Silurian	35	First land plants and large coral reefs		
		Ordovician	70	First vertebrates (fish) appear		
		Cambrian	70	Marine shelled invertebrates (earliest abundant fossils)		
Precambrian time	Precambrian	Late Precambrian		Marine invertebrates, mainly without shells: bacteria, sponges, worms	Early supercontinent forms	
		Early Precambrian		Primitive bacteria and algae		

Table 16-1

The Planets

Planet	Symbol	Mean Distance from Sun, Earth = 1 ^a	Diameter, Thousands of km	Mass, Earth = 1 ^b	Mean Density, Water = 1 ^c	Surface Gravity, Earth = 1 ^d	Escape Speed, km/s ^e	Period of Rotation on Axis	Period of Revolution around Sun	Eccentricity of Orbit ^h	Inclination of Orbit to Ecliptic ⁱ	Known Satellites ^j
Mercury		0.39	4.9	0.055	5.4	0.38	4.3	59 days	88 days	0.21	7°00'	0
Venus		0.72	12.1	0.82	5.25	0.90	10.4	243 days ^f	225 days	0.01	3°34'	0
Earth		1.00	12.7	1.00	5.52	1.00	11.2	24 h	365 days	0.02	—	1
Mars		1.52	6.8	0.11	3.93	0.38	5.0	24.5 h	687 days	0.09	1°51'	2
Jupiter		5.20	143	318	1.33	2.6	60	10 h	11.9 yr	0.05	1°18'	61
Saturn		9.54	120	95	0.71	1.2	36	10 h	29.5 yr	0.06	2°29'	39
Uranus		19.2	51	15	1.27	1.1	22	16 h ^g	84 yr	0.05	0°46'	24
Neptune		30.1	50	17	1.70	1.2	24	16 h	165 yr	0.01	1°46'	8
Pluto		39.4	2.4	0.03	1.99	0.43	3.2	6 days	248 yr	0.25	17°12'	1

^aThe mean earth-sun distance is called the astronomical unit, where 1 AU = 1.496×10^8 km.

^bThe earth's mass is 5.98×10^{24} kg.

^cThe density of water is $1 \text{ g/cm}^3 = 10^3 \text{ kg/m}^3$.

^dThe acceleration of gravity at the earth's surface is 9.8 m/s^2 .

^eSpeed needed for permanent escape from the planet's gravitational field.

^fVenus rotates in the opposite direction from the other planets.

^gThe axis of rotation of Uranus is only 8° from the plane of its orbit.

^hThe difference between the minimum and maximum distances from the sun divided by the average distance.

ⁱThe ecliptic is the plane of the earth's orbit.

^jProbably more small ones around Jupiter, Saturn and Uranus.

Preface

Creating Informed Citizens

The aim of *The Physical Universe* is to present, as simply and clearly as possible, the essentials of physics, chemistry, earth science, and astronomy to students whose main interests lie elsewhere.

Because of the scope of these sciences and because we assume minimal preparation on the part of the reader, our choice of topics and how far to develop them had to be limited. The emphasis throughout is on the basic concepts of each discipline. We also try to show how scientists approach problems and why science is a never-ending quest rather than a fixed set of facts. The book concentrates on those aspects of the physical sciences most relevant to a nonscientist who wants to understand how the universe works and to know something about the connections between science and everyday life. We hope to equip readers to appreciate major developments in science as they arrive and to be able to act as informed citizens on matters that involve science and public policy.

Two features of the book emphasize the human element. One is a series of biographies of important contributors to the physical sciences from Archimedes to today. The other consists of essays by distinguished young scientists—Timothy C. Miller (a physicist), Cynthia M. Friend (a chemist), Andrea Donnellan (a geophysicist), and Wendy Freedman (an astronomer)—which give an idea of what a typical day at work involves for each of them and nicely conveys the excitement of being at the frontier of knowledge.

"This is a well-written book. The authors cover the key topics at a level that is effective for the proposed audience. There are lots of figures that assist the written presentation. The end-of-chapter problems are excellent in that many of them ask the student to apply material rather than recite it. The many biographies put a face on science. The book earns a grade of A."

—Peter Hamlet, *Pittsburg State University*

Scope and Organization

There are many possible ways to organize a book of this kind. We chose the one that provides the most logical progression of ideas, so that each new subject builds on the ones that came before.

"One strength is its organizational style—beginning with physics, moving to chemistry, and then applying this knowledge to the weather, geology, and astronomy. The first chapter is a particular



strength—discussing the nature of science and science as a process with some examples. Finally, I believe that the book is generally well laid out in its visual appearance: the figures do a good job of supplementing the text.”

—Jennifer J. Birriel, *Morehead State University*

Our first concern in *The Physical Universe* is the scientific method, using as illustration the steps that led to today's picture of the universe and the earth's place in it. Next we consider motion and the influences that affect moving bodies. Gravity, energy, and momentum are examined, and the theory of relativity is introduced. Matter in its three states next draws our attention, and we pursue this theme from the kinetic-molecular model to the laws of thermodynamics and the significance of entropy. A grounding in electricity and magnetism follows, and then an exploration of wave phenomena that includes the electromagnetic theory of light. We go on from there to the atomic nucleus and elementary particles, followed by a discussion of the quantum theories of light and of matter that lead to the modern view of atomic structure.

“The strongest feature of the text is its introduction. The first chapter establishes a pertinent theme that unifies the text. The authors do an excellent job of defining the scientific method and using the historical development of how the “heavens” are viewed to exemplify their approach. There are also many examples where the ideas introduced in chapter one are reinforced in subsequent chapters. Artificial satellites, rockets, the fate of the universe, and the Doppler effect all build on the initial ideas and themes.”

—Capp Yess, *Morehead State University*

“This is exactly what I teach! . . . very well written. I liked the way the relation between distance, velocity, and time are shown . . . the way Newton's Laws are presented. The discussion on “Why Satellites Don't Fall Down” is nicely written for the students.”

—Kingshuk Majumdar, *Berea College*

The transition from physics to chemistry is made via the periodic table. A look at chemical bonds and how they act to hold together molecules, solids, and liquids is followed by a survey of chemical reactions, organic chemistry, and the chemistry of life.

“In my 36 years of teaching chemistry and physics, I have discovered that spending a quality and quantity of time on the Periodic Law and the Periodic Table can prove very interesting to students and can open up many areas of understanding of chemistry topics which naturally follow. This chapter [chapter 9] does an EXCELLENT job of introducing and elaborating on the logical organization of the Table and how essential it is to a basic understanding of the many phases and combinations of matter.”

—William M. Scott, *Fort Hays State University*

Our concern now shifts to the planet on which we live, and we begin by inquiring into the oceans of air and water that cover it. From

there we proceed to the materials of the earth, to its ever-evolving crust, and to its no-longer-mysterious interior. After a brief narrative of the earth's geological history we go on to what we know about our nearest neighbors in space—planets and satellites, asteroids, meteoroids, and comets.

Now the sun, the monarch of the solar system and the provider of nearly all our energy, claims our notice. We go on to broaden our astronomical sights to include the other stars, both individually and as members of the immense assemblies called galaxies. The evolution of the universe starting from the big bang is the last major subject, and we end with the origin of the earth and the likelihood that other inhabited planets exist in the universe and how we might communicate with them.

"With the various spacecraft in the last couple of decades, the Hubble Space Telescope, and the ongoing study of lunar samples and meteorites, there is an immense amount of information that is available for inclusion in a chapter [chapter 16] such as this. The authors have done an excellent job of deciding what to include, and the result is an excellent overview chapter that is as current as it can be in this rapidly growing subject."

—Eric Jerde, Morehead State University

"This is one of the best chapters [chapter 17] on stars in a text of this level that I have read. It addresses the various aspects of the stars (size, distance, evolution, etc.) in an easy to understand manner. It also provides information concerning the history of the current knowledge of stars."

—Wilda Pounds, Northeast Mississippi Community College

Mathematical Level

The physical sciences are quantitative, which has both advantages and disadvantages. On the plus side, the use of mathematics means that every concept must be in the form of a clear, definite statement whose predictions can be tested objectively. Less welcome is the discomfort many of us feel when faced with mathematical reasoning and calculations. To minimize such discomfort, previous editions of *The Physical Universe* used mathematical arguments sparingly, which meant that an important part of the story of how physics and chemistry work to make sense of the natural world and how their findings led to the technological world of today could only be hinted at.

At the request of many teachers who feel their students are able and willing to go further, the book now uses mathematics a little more freely than before. As a result, it is no longer necessary to pull the kinetic energy formula $\frac{1}{2}mv^2$ out of a hat, for instance, and how the mole connects chemical ideas with the real world can be explored. Nevertheless, the mathematical level remains modest, and the new material, which supplements rather than dominates the presentation, does not have to be mastered to understand the rest of the book. The basic algebra needed is reviewed in the Math Refresher. Powers-of-ten notation for

small and large numbers is carefully explained there. This section is selfcontained and can provide all the math background needed.

New To This Edition

Because the organization of the previous edition worked well in the classroom, it was not changed. In addition to the somewhat greater use of mathematics mentioned above, the changes for this edition came under four headings.

New Topics The coverage was expanded by adding a variety of new material, for example on accelerated motion, specific heat capacity, pressure in a fluid, the nature of charge, index of refraction, ray tracing, the periodic table, colloids, quantitative chemistry, dew point, Portland cement, mass extinctions, gamma-ray bursts, and dark energy.

Updating Recent findings and their interpretations were incorporated where appropriate. The sections dealing with energy generation and use, the solar system, and the evolution of the universe received particular attention.

Illustrations The illustrations, both line drawings and photographs, are full partners to the text and provide a visual pathway to understanding scientific observations and principles for students unaccustomed to abstract argument. Thirty-eight new illustrations are included in this edition.

Exercises A number of exercises of each kind were replaced and many new ones added to give a total of 1686, an average of over ninety per chapter.

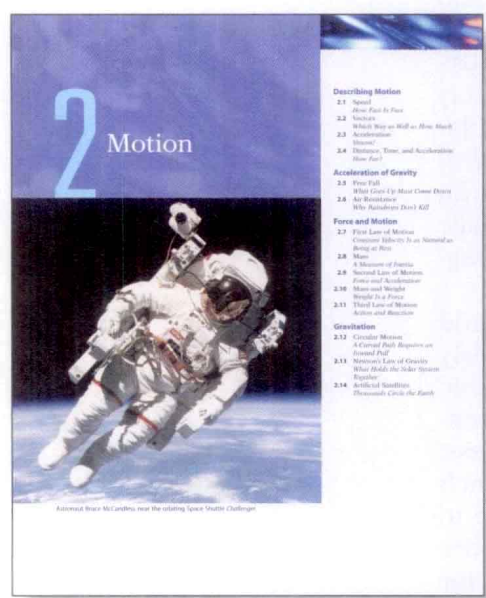
The Learning System

A variety of aids are provided in *The Physical Universe* to help the reader master the text.

Chapter Outline A preview of major topics is included on the opening page of each chapter, showing at a glance what the chapter covers.

Bringing Science to Life

Worked Examples A full grasp of physical and chemical ideas includes an ability to solve problems based on these ideas. Some students, although able to follow the discussions in the book, nevertheless may have trouble putting their knowledge to use in this way. To help them, detailed solutions of typical problems are provided that show how to apply formulas and equations to real-world situations. Besides the worked examples, outline solutions for half the end-of-chapter problems are given at the end of the text, for a total of nearly 200 model solutions. Thinking



through these solutions should bring the unsolved even-numbered problems within reach. Besides its role in reinforcing the understanding of physical and chemical ideas, solving problems can provide great pleasure, and it would be a shame to miss out on this pleasure.

"The examples in text are good, well illustrated and use unit analysis effectively. The examples are routinely followed at the end of the chapter with similar problems."

—Capp Yess, Morehead State University

Biographies Brief biographies of 40 major figures in the development of the physical sciences appear where appropriate throughout the text. The biographies provide human and historical perspectives by attaching faces and stories to milestones in these sciences.

"I like the biographies and information boxes that are appropriately placed throughout the chapters. It provides a connection between the material the students are learning and the people that helped to bring that information to them."

—Timothy T. Ehler, Buena Vista University

Sidebars These are brief accounts of topics related to the main text. A sidebar may provide additional information on a particular subject, comment on its significance, describe its applications, consider its historical background, or present recent findings.

"In the physics section, in which most of the fundamental principles were discovered decades ago, the coverage still is current because the authors use examples from current topics. . . . The examples and sidebar topics are from very current research. Examples include the discussions of maglev trains, wind energy and solar cells, gravitational waves etc."

—Kent J. Price, Morehead State University

At Work Essays Four young scientists who have carried out important research in their respective fields have contributed accounts of how their days at work are spent. The enthusiasm and dedication they bring to their probes of the physical universe show clearly in these essays.

End of Chapter Features

Important Terms and Ideas Important terms introduced in the chapter are listed together with their meanings, which serves as a chapter summary. A list of the **Important Formulas** needed to solve problems based on the chapter material is also given where appropriate.

Force and Motion 2-19 47

Muscular Forces

The force an animal exerts results from contractions of its skeletal muscles, which occur when the muscles are electrically stimulated by nerves. The maximum force a muscle can exert is proportional to its cross-sectional area and can be as much as 70 N/cm² (100 lb/in²). An athlete might have a biceps muscle in his arm 4 cm across, so it could produce up to 1960 N (440 lb) of force. This is a lot, but the geometry of an animal's skeleton and its muscles limits the force it can exert. As a result, the actual force a person's arm can exert is much smaller than the forces exerted by the arm muscles themselves, but the primary arm can move through a much greater distance than the amount the muscles contract.

An animal whose length is L has muscles that have cross-sectional areas and hence strengths roughly proportional to L^2 . But the

size of the animal depends on its volume, which is roughly proportional to L^3 . Therefore the larger an animal is, in general, the weaker it is relative to its mass. This is obviously in nature. For instance, even though insects can carry loads several times their weights, whereas animals the size of humans are limited to loads comparable with their weights.

know exactly what we mean, and we know exactly how an object free to move will respond when a given force acts on it.

The Newton The second law of motion shows us how to define a unit for force. If we express mass in kilograms and acceleration in m/s^2 , force F is given in terms of kilograms. This unit is given a special name: the **newton (N)**. Thus

$$1 \text{ newton} = 1 \text{ N} = 1 \text{ kg(m/s}^2\text{)}$$

When a force of 1 N is applied to a 1-kg mass, the mass is given an acceleration of 1 m/s^2 (Fig. 2-25).

In the British system, the unit of force is the **pound (lb)**. The pound and the newton are related as follows:

$$1 \text{ N} = 0.225 \text{ lb}$$

$$1 \text{ lb} = 4.45 \text{ N}$$

Example 2-9

When a tennis ball is served, it is in contact with the racket for a time that is typically 0.005 s, which is 5 thousandths of a second. Find the force needed to serve a 60-g tennis ball at 30 m/s .

Since the ball starts from rest, $v_i = 0$, and its acceleration when struck by the racket is, from Eq. 2-8,

$$a = \frac{v_f - v_i}{t} = \frac{30 \text{ m/s} - 0}{0.005 \text{ s}} = 6000 \text{ m/s}^2$$

Because the ball's mass is 60 g = 0.06 kg, the force the racket must exert on it is

$$F = ma = (0.06 \text{ kg})(6000 \text{ m/s}^2) = 360 \text{ N}$$

In more familiar units, this force is 81 lb. Of course, it does not impart so great a force to the racket (Fig. 2-26).



Figure 2-24 The relationship between force and acceleration means that the less acceleration something has, the smaller the net force on it. If you drop to the ground from a height, as this jumper has, you can reduce the force of the impact by bending your knees as you hit the ground to increase the time during which you come to a full stop. The same reasoning can be applied to make

The Inner Planets

BIOGRAPHY Carl Sagan (1914-1996)

Born in Brooklyn, New York, Sagan studied physics and astronomy at Cornell and the University of Chicago. After a period at Harvard, he returned to Cornell, where he was a professor until his death. Sagan contributed to the understanding of many aspects of planetary science, for example the role of the greenhouse effect in heating the surface of Venus, how wind-blown dust causes seasonal changes in the appearance of Mars, and the nature of the organic molecules in the reddish clouds on Titan's satellite, Titan. His studies of the long-term effects of nuclear war on the earth

were very influential. Sagan was involved in the research programs of the *Mariner*, *Viking*, *Voyager*, and *Galileo* spacecrafts, and many of today's planetary scientists were his students or coworkers. An inspiring and prolific popularizer of science, his television series *Cosmos* was watched by 500 million people around the world, and the book based on the series became the best-selling science book ever published in English. Sagan was the author or coauthor of more than 600 papers and articles and 20 books, one of which won a Pulitzer prize.



How often asteroids of various sizes collide with the earth can be estimated from their numbers in space and the distribution of crater sizes on the moon (where there is no erosion, unlike the earth). Fig. 16-24 shows how the probable impact frequency varies with asteroid size. An asteroid 2 km across, which can be expected to strike the earth an average of every million years, is the smallest that could create catastrophe on a global scale. Its impact would release energy equivalent to 100,000 megatons of TNT (over 10,000 times the energy of the largest hydrogen bomb ever tested—and leave a crater 50 km across). Hundreds of asteroids of that size or larger have been detected that periodically pass near the earth's orbit, and there are no doubt many more. Of the large asteroids that are being tracked, the one that will come closest to the earth in this century has an estimated mass of

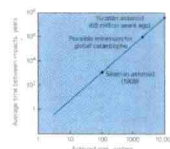


Figure 16-24 Large asteroids are much less likely to strike the earth than small ones, but their more than 2 km across would devastate life on earth. (The scales are not linear.)

Exercises

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Important Terms and Ideas

Solids that consist of particles arranged in repeated patterns are called **crystalline**. If the particles are arranged randomly, the solid is called **amorphous**. The four types of bonds are **ionic**, **covalent**, **metallic**, and **molecular**.

The **metallic bond** arises from a "sea" of electrons that can move freely through a solid metal. These electrons are also responsible for the ability of metals to conduct heat and electricity well.

Van der Waals forces arise from the electric attraction between constantly changing distributions in atoms and molecules. They enable atoms and molecules to form solids without bonding or transferring electrons.

In a solution, the substance present in larger amount is the **solvent**; the other is called the **solute**. If the solute is dissolved in a liquid, the liquid is always considered the solvent. The **solubility** of a substance is the maximum amount that can be dissolved in a given quantity of solvent at a given temperature. A **saturated** solution is one that contains the maximum amount of solute possible.

Polar molecules have at least one negatively charged atom and one positively charged atom. In **amphipolar molecules**, charges are uniformly distributed on the average. **Polar liquids** dissolve only some and polar

covalent compounds, whereas **nonpolar liquids** dissolve only nonpolar covalent compounds. **Water** is a highly polar liquid, which is why it is so good a solvent. **Acids**, compounds that differ from those of the corresponding neutral substance, are **electrolytes** in any substance that separates into ions when dissolved in water. Solutions of **acids** in water contain H^+ ions; solutions of **bases** in water contain OH^- ions. **Strong acids** and **bases** dissociate completely in solution; **weak acids** and **bases** only partially. The pH of a solution is a measure of its degree of acidity or basicity. Acid solutions have pH values of less than 7; basic solutions have pH values of more than 7. A **neutral solution** is neither acid nor basic and has a pH of 7.

In acid-base **neutralization**, H^+ and OH^- ions join to form H_2O molecules.

Salts are usually crystalline solids that consist of positive and negative ions. A **strong electrolyte** can be formed by neutralizing an acid that contains the appropriate metal ion with the base that contains the appropriate nonmetal ion and then evaporating the solution to dryness.

Exercises: Multiple Choice

1. An amorphous solid
 - a. has its particles arranged in a regular pattern
 - b. is held together by ionic bonds
 - c. does not melt at a definite temperature but softens gradually
 - d. contains no polar molecules
2. Ionic crystals
 - a. contain a "sea" of freely moving electrons
 - b. consist of either positive or negative ions only
 - c. dissolve only in polar liquids
 - d. are soft and melt at low temperatures
3. A "sea" of freely moving electrons is present in
 - a. ionic crystals
 - b. molecular crystals
 - c. covalent crystals
 - d. metal crystals
4. A polar molecule can attract
 - a. only ions
 - b. only other polar molecules
 - c. electron transfer
 - d. electron sharing
5. Which solids have the lowest melting points?
 - a. ionic
 - b. ionic
 - c. van der Waals
 - d. metallic
6. Which solids are the best electrical conductors?
 - a. ionic
 - b. ionic
 - c. van der Waals
 - d. metallic
7. Diamond and graphite both
 - a. conduct electricity well
 - b. can be used as lubricants
 - c. are very hard
 - d. have CO_2 when burned in air
8. Suppose there were molecules that had no attraction between them. A collection of such molecules would be a(n)
 - a. amorphous solid
 - b. crystalline solid
 - c. ionic solid
 - d. molecular solid

Exercises

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(vertical size and distance above the water)? Use a diagram to explain your answer, and assume that the fish's eye and brain, like the human eye and brain, are accustomed to interpreting light rays as straight lines.

23. Does a spherical bubble in a pane of glass act to converge or diverge light passing through it?

24. A coin is placed at a focal point of a converging lens. Is an image formed? If yes, is it real or virtual? Is it inverted, larger or smaller than the object?

25. Under what circumstances, if any, will a light ray that passes through a converging lens not be deviated? Under what circumstances, if any, will a light ray that passes through a diverging lens not be deviated?

26. Under what circumstances, if any, will a converging lens form an inverted image of a real object? Under what circumstances, if any, will a diverging lens form an erect image of a real object?

27. Is the mercury column in a thermometer wider or narrower than it needs to be?

28. To their eyes, in which is a converging lens, do they see a virtual image of a real object? Is there any size in which a diverging lens, by itself, can form a real image of a real object?

29. When it leaves the lens, which path will the incoming ray in Fig. 6-49 follow?

30. Describe the image the lens of the eye forms on the retina.

31. When white light is dispersed by a glass prism, red light is bent least and violet light is bent most. What does this tell you about the relative speeds of red and violet light in glass?

32. When a beam of white light passes perpendicular through a flat pane of glass, is it not dispersed into a spectrum? Why not?

Problems

1. An opera performance is being broadcast by radio. Will it be a certain sound level, a member of the audience 50 m from the stage or a listener 5 m from the radio receiver 5000 km away?

2. A radar signal takes 2.7×10^{-5} s to go to the moon and return. How far away was the moon at that time?

3. A person is watching an airplane being driven to a test site in a plane. The sound of each blade of the propeller is 1.44 m through the tail and 2.0 m

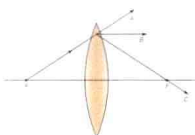


Figure 6-49

33. What color would red light appear if it were illuminated by (a) white light (b) red light (c) green light?

34. (a) What would the American flag look like when viewed with red light? (b) What would the flag look like when viewed with green light?

35. Light of what color is scattered most in the atmosphere? Least?

36. If the earth had no atmosphere, what would the color of the sky be during the day?

37. How can constructive and destructive interference be reconciled with the principle of conservation of energy?

38. Give two advantages that a telescope lens or mirror of large diameter has over one of small diameter.

39. Radio waves are able to diffract around buildings, as are light waves. Why are light waves not diffracted around buildings, as are radio waves? Why not?

40. An airplane is flying at 600 km/h at an altitude of 2 km. What is the speed of the airplane's shadow on the ground as it is being seen from the ground?

41. Find the frequency of sound waves in air whose wavelength is 25 cm.

"The 'key ideas' discussion is a great idea, particularly with 'bold' words for those words that may be unfamiliar to some students."

—T.D. Sauncy, Angelo State University

There are a variety of exercises, questions, and problems on all levels of difficulty following each chapter. They are of three kinds:

Multiple-Choice Exercises An average chapter has 38 multiple-choice exercises (with answers) that act as a quick, painless check on understanding. Correct answers provide reinforcement and encouragement; incorrect ones identify areas of weakness.

Questions Some of the questions are meant to find out how well the reader has understood the chapter material. Others ask the reader to apply what he or she has learned to new situations. Answers to the odd-numbered questions are given at the back of the book.

Problems The physics and chemistry chapters include problems that range from quite easy to moderately challenging. The ability to work out such problems signifies a real understanding of these subjects. Outline solutions (not just answers) for the odd-numbered problems are given at the back of the book.

"The end of chapter material is very useful. Exercises, questions, and problems are comprehensive—there are exercises for quick review, questions to spur deeper thought about the material, and problems to test student ability to apply the chapter material. Having outlines of the odd-numbered problems instead of answers only is very helpful to the students."

—Kent J. Price, Morehead State University

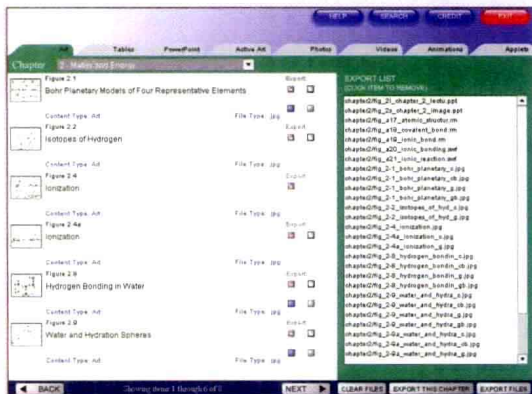
Additional Resources for The Physical Universe

Digital Content Manager

The **Digital Content Manager** contains jpeg files of the four-color images, tables, and worked examples from the text as well as a selection of animations and PowerPoints of the text images and sample lectures. These digital assets are contained on a cross-platform CD-ROM and are grouped by chapter within a user-friendly interface. With the help of these valuable resources, instructors can create customized classroom presentations, visually based tests and quizzes, dynamic course website content, and attractive printed support materials.

"Obviously, much work has been put into producing a book that will keep the interest of students. The illustrations, charts, and photos are timely and well done."

—Wilda Pounds, Northeast Mississippi Community College



Online Learning Center

McGraw-Hill's Online Learning Center for *The Physical Universe* is a complete online self-study and course resource system. The Online Learning Center is customized to Krauskopf and Beiser's *The Physical Universe* textbook. Instructors have access to the fully downloadable instructor's manual. The instructor's manual, written by the text authors, provides answers and solutions to the even-numbered end-of-chapter questions and problems not provided in the text. The Online Learning Center also contains the figures from the text in jpeg format; text-specific questions in CPS eInstruction format; daily concept quizzes for just-in-time teaching techniques; sample PowerPoint lectures; animations; links to resources; clip art; and many other features.

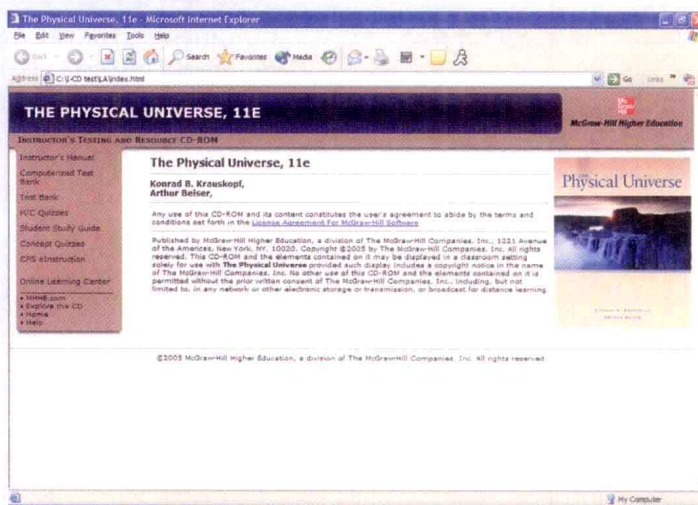
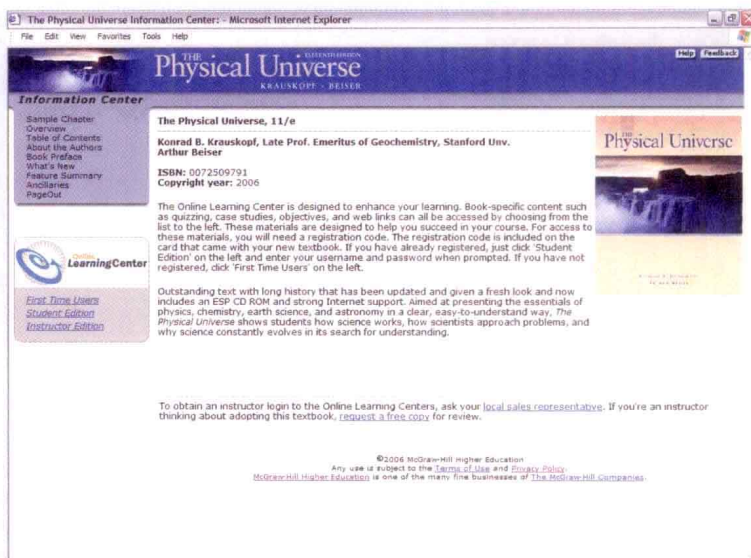
Students can use the Online Learning Center to study in a variety of ways. Many learning aids to test understanding of chapter concepts are available, such as, self-quizzes in multiple-choice and matching formats with online feedback. Other items correlated to the main text include chapter goals, outlines, and weblinks. The Online Learning Center also includes a collection of animations to help students visualize concepts and up-to-the minute news feeds on current physical science topics.

CPS eInstruction

The Classroom Performance System (CPS) brings interactivity into the classroom or lecture hall. It is a wireless response system that gives the instructor and students immediate feedback from the entire class. The wireless response pads are essentially remotes that are easy to use and engage students. CPS allows instructors to motivate student preparation, interactivity, and active learning. Instructors receive immediate feedback to assess which concepts students understand. Questions covering the content of the *Physical Universe* text and formatted in the CPS eInstruction software are available on the *Physical Universe* Online Learning Center.

Instructor's Testing and Resource CD-ROM

The cross-platform CD-ROM contains the Instructor's Manual and Test Bank, available in both Word and PDF formats. The instructor's manual, written by the text authors, provides answers and solutions to the even-numbered end-of-chapter questions and problems not



provided in the text. The Test Bank of over 900 additional questions and problems can be used for homework assignments and/or the preparation of exams. These additional Test Bank questions are also included on the CD-ROM within a computerized test bank. This user-friendly software can be used to quickly create customized exams by allowing instructors to sort questions by format; edit existing questions or add new ones; and scramble questions for multiple versions of the same test. Files for other questions from the online learning center quizzes, the student study guide, and CPS eInstruction are also provided on the CD-ROM.

Student Study Guide

Another helpful resource can be found in *The Physical Universe* Student Study Guide. With this Study Guide, students will maximize their use of *The Physical Universe* text package. It supplements the text with additional, self-directed activities and complements the text by focusing on the important concepts, theories, facts, and processes presented by the authors.

Overhead Transparencies

A set of over 100 full-color transparencies features images from the text. The images have been modified to ensure maximum readability in both small and large classroom settings.

Primis Online

This text can be customized in print or in an electronic format to meet exact course needs. McGraw-Hill's Primis Online allows instructors to select desired chapters and preferred sequence and to choose supplements from the many science items on our database. Visit <http://www.primiscontentcenter.com/> to begin today.

Acknowledgments

Comments from users have always been of much help in revising *The Physical Universe*. Detailed reviews of its tenth edition by the following teachers were especially valuable and are much appreciated:

Paul E. Adams, Fort Hays State University
Robert J. Backes, Pittsburg State University

Mohammad Bhatti, The University of Texas Pan American

Ignacio Birriel, Morehead State University
Jennifer J. Birriel, Morehead State University

Charles C. Blatchley, Pittsburg State University

Art Braundmeier, Jr., Southern Illinois University, Edwardsville

Peter E. Busher, Boston University
Francis Cobbina, Columbus State Community College

Paul J. Dolan, Jr., Northeastern Illinois University

Timothy T. Ehler, Buena Vista University
Carl K. Frederickson, University of Central Arkansas

Peter Hamlet, Pittsburg State University
Timothy G. Heil, University of Georgia

C. A. Hughes, University of Central Oklahoma

Eric Jerde, *Morehead State University*
Booker Juma, *Fayetteville State University*
Sher S. Kannar, *Stillman College*
Eric T. Lane, *The University of Tennessee*
at Chattanooga
Kingshuk Majumdar, *Berea College*
Alan Marscher, *Boston University*
T. Ted Morishige, *University of Central*
Oklahoma
Wilda Pounds, *Northeast Mississippi*
Community College

Kent J. Price, *Morehead State University*
Lee Roecker, *Berea College*
T. D. Sauncy, *Angelo State University*
Robert M. Schoch, *Boston University*
William M. Scott, *Fort Hays State*
University
Tom Shoberg, *Pittsburg State University*
Ling Jun Wang, *University of Tennessee at*
Chattanooga
Capp Yess, *Morehead State University*

Many constructive suggestions, new ideas, and invaluable advice were also provided by reviewers of earlier editions. Special thanks are owed to those who reviewed the text in the past:

William K. Adeniyi, *North Carolina A&T*
State University
Brian Adrian, *Bethany College*
Z. Altounian, *McGill University*
I. J. Aluka, *Prairie View A&M University*
Louis G. Arnold, *Otterbein College*
Jose D'Arruda, *University of North*
Carolina—Pembroke
Robert Backes, *Pittsburg State*
University
Terry Bradfield, *Northeastern State*
University
Jeanne M. Buccigross, *College of Mount*
St. Joseph
Korey Champe, *Bakersfield Junior College*
Edward S. Chang, *University of*
Massachusetts, Amherst
Tu-nan Chang, *University of Southern*
California
Michael R. Cohen, *Shippensburg*
University
Whitman Cross II, *Towson State*
University
William C. Culver, *St. Persburg Junior*
College
John Encarnación, *Saint Louis University*
Bernd Enders, *College of Marin*
Terry Engelder, *Pennsylvania State*
University
Frederick Floodstrand, *Arkansas State*
University
Andrea M. Gorman Gelder, *University of*
Maine at Presque Isle
William Gregg, *Louisiana State University*
Austin F. Gulliver, *Brandon University*
Kenny Hebert, *Carl Albert State College*
Esmail Hejazifar, *Wilmington College*
Jean-Francois Henry, *Northern Virginia*
Community College
J. Horacio Hoyos, *St. Persburg Junior*
College
Lauree Lane, *Tennessee State University*

Benjamin K. Malphrus, *Morehead State*
University
Garry Noe, *Virginia Wesleyan College*
John Oakes, *Marian College*
Patrick Owens, *Winthrop University*
Patrick Papin, *San Diego State*
University
James D. Patterson, *Florida Institute of*
Technology
A. G. Unil Perera, *Georgia State*
University
Brian L. Pickering, *North Central*
Michigan College
Jerry Polson, *Southeastern Oklahoma*
State University
Jeff Robertson, *Arkansas Technical*
University
Charles Rop, *University of Toledo*
Klaus Rossberg, *Oklahoma City*
University
Jack Ryan, *South Arkansas Community*
College
Eric Schulman, *University of Virginia*
Regina Schulte-Ladbeck, *University of*
Pittsburgh
David A. Slimmer, *Lander University*
Frederick R. Smith, *Memorial University*
of Newfoundland
Pam Smith, *Cowley County Community*
College
John H. Summerfield, *Missouri Southern*
State College
Sergio E. Ulloa, *Ohio University*
Wytse van Dijk, *Redeemer College*
Peter van Keken, *University of Michigan*
Daniel A. Veith, *Nicholls State University*
William J. Wallace, *San Diego State*
University
Sylvia Washington, *Elgin Community*
College
Heather L. Woolverton, *University of*
Central Arkansas

Nancy Woods of Des Moines Area Community College compiled the Videolists in the *Instructor's Manual/Test Bank for The Physical Universe*.

It is with great sadness that I have to report the death of Konrad B. Krauskopf on May 8, 2003. We worked together for 45 years on this and other books, and I will miss his wise counsel.

Finally, I want to thank my friends at McGraw-Hill for their skilled and dedicated help in producing this edition.

Arthur Beiser

Meet the Authors

Konrad B. Krauskopf was born and raised in Madison, Wisconsin and earned a B.S. in chemistry from University of Wisconsin in 1931. He then earned a Ph.D. in chemistry at the University of California in Berkeley. When the Great Depression made jobs in chemistry scarce, Professor Krauskopf decided to study geology, which had long fascinated him. Through additional graduate work at Stanford University, he earned a second Ph.D. and eventually a position on the Stanford faculty. He remained at Stanford until his retirement in 1976. During his tenure, Professor Krauskopf also worked at various times with the U.S. Geological Survey, served with the U.S. army in occupied Japan, and traveled to Norway, France, and Germany on sabbatical leaves. His research interests include field work on granites and metamorphic rocks and laboratory study on applications of chemistry to geologic problems, especially the formation of ore deposits. In recent years, Professor Krauskopf has spent time working with various government agencies on the problem of radioactive waste disposal.

Arthur Beiser, a native of New York City, received B.S., M.S., and Ph.D. degrees in physics from New York University, where he later served as Associate Professor of Physics. He then was Senior Research Scientist at the Lamont Geological Observatory of Columbia University. His research interests were chiefly in cosmic rays and magnetohydrodynamics as applied to geophysics and astrophysics. In addition to theoretical work, he participated in a cosmic-ray expedition to an Alaskan peak and directed a search for magnetohydrodynamic waves from space in various Pacific locations. He is the author or coauthor of 36 books, mostly college texts on physics and mathematics, 14 of which have been translated into a total of 21 languages. Two of his books are on sailing, *The Proper Yacht* and *The Sailor's World*. Figure 12-18 is a photograph of Dr. Beiser at the helm of his 58-ft sloop.

The Periodic Table of the Elements

Group

1

2

3

4

5

6

7

8

Period

1

2

3

4

5

6

7

1

H

Hydrogen

1.008

2

Li

Lithium

6.941

3

Na

Sodium

22.99

4

K

Potassium

39.10

5

Rb

Rubidium

85.47

6

Cs

Cesium

132.9

7

Fr

Francium

(223)

4

Be

Beryllium

9.012

11

Na

Sodium

22.99

12

Mg

Magnesium

24.31

19

K

Potassium

39.10

37

Rb

Rubidium

85.47

55

Cs

Cesium

132.9

87

Fr

Francium

(223)

20

Ca

Calcium

40.08

38

Sr

Strontium

87.62

56

Ba

Barium

137.3

88

Ra

Radium

226.0

21

Sc

Scandium

44.96

39

Y

Yttrium

88.91

57

La

Lanthanum

138.9

72

Hf

Hafnium

178.5

104

Rf

Rutherfordium

(261)

22

Ti

Titanium

47.88

40

Zr

Zirconium

91.22

73

Ta

Tantalum

180.9

105

Db

Dubnium

(262)

23

V

Vanadium

50.94

41

Nb

Niobium

92.91

74

W

Tungsten

183.9

106

Sg

Seaborgium

(263)

24

Cr

Chromium

52.00

42

Mo

Molybdenum

95.94

76

Os

Osmium

190.2

108

Hs

Hassium

(265)

25

Mn

Manganese

54.94

43

Tc

Technetium

(98)

75

Re

Rhenium

186.2

107

Bh

Bohrium

(262)

26

Fe

Iron

55.8

44

Ru

Ruthenium

101.1

77

Ir

Iridium

192.2

109

Mt

Meitnerium

(266)

27

Co

Cobalt

58.93

45

Rh

Rhodium

102.9

78

Pt

Platinum

195.1

110

Ds

Darmstadtium

(271)

28

Ni

Nickel

58.69

46

Pd

Palladium

106.4

79

Au

Gold

197.0

111

Rg

Roentgenium

(272)

29

Cu

Copper

63.55

47

Ag

Silver

107.9

80

Hg

Mercury

200.6

112

Cn

Copernicium

(285)

30

Zn

Zinc

65.39

48

Cd

Cadmium

112.4

81

Tl

Thallium

204.4

113

Nh

Nihonium

(286)

31

Ga

Gallium

69.72

49

In

Indium

114.8

82

Pb

Lead

207.2

114

Fl

Flerovium

(289)

32

Ge

Germanium

72.59

50

Sn

Tin

118.7

83

Bi

Bismuth

209.0

115

Mc

Moscovium

(290)

33

As

Arsenic

74.92

51

Sb

Antimony

121.8

84

Po

Polonium

(209)

116

Lv

Livermorium

(293)

34

Se

Selenium

78.96

52

Te

Tellurium

127.6

85

At

Astatine

(210)

117

Ts

Tennessine

(294)

35

Br

Bromine

79.90

53

I

Iodine

126.9

86

Rn

Radon

(222)

118

Og

Oganesson

(294)

36

Kr

Krypton

83.80

54

Xe

Xenon

131.8

88

Ra

Radium

226.0

119

Uut

Ununtrium

(295)

37

Sr

Strontium

87.62

55

Cs

Cesium

132.9

89

Ac

Actinium

(227)

120

Uuq

Ununquadium

(296)

38

Sr

Strontium

87.62

56

Ba

Barium

137.3

90

Th

Thorium

232.0

121

Uub

Ununbium

(297)

39

Y

Yttrium

88.91

57

La

Lanthanum

138.9

91

Pa

Protactinium

231.0

122

Uub

Ununbium

(297)

40

Zr

Zirconium

91.22

58

Ce

Cerium

140.1

92

U

Uranium

238.0

123

Uut

Ununtrium

(298)

41

Nb

Niobium

92.91

59

Pr

Praseodymium

140.9

93

Np

Neptunium

(237)

124

Uuq

Ununquadium

(299)

42

Mo

Molybdenum

95.94

60

Nd

Neodymium

144.2

94

Pu

Plutonium

(244)

125

Uub

Ununbium

(299)

43

Tc

Technetium

(98)

61

Pm

Promethium

(145)

95

Am

Americium

(243)

126

Uut

Ununtrium

(300)

44

Ru

Ruthenium

101.1

62

Sm

Samarium

150.4

96

Cm

Curium

(247)

127

Uuq

Ununquadium

(300)

45

Rh

Rhodium

102.9

63

Eu

Europium

152.0

97

Bk

Berkelium

(247)

128

Uub

Ununbium

(300)

46

Pd

Palladium

106.4

64

Gd

Gadolinium

157.3

98

Cf

Californium

(251)

129

Uut

Ununtrium

(301)

47

Ag

Silver

107.9

65

Tb

Terbium

158.9

99

Es

Einsteinium

(252)

130

Uuq

Ununquadium

(301)

48

Cd

Cadmium

112.4

66

Dy

Dysprosium

162.5

100

Fm

Fermium

(257)

131

Uub

Ununbium

(301)

49

In

Indium

114.8

67

Ho

Holmium

164.9

101

Md

Mendelevium

(260)

132

Uut

Ununtrium

(302)

50

Sn

Tin

118.7

68

Er

Erbium

167.3

102

No

Nobelium

(259)

133

Uuq

Ununquadium

(302)

51

Sb

Antimony

121.8

69

Tm

Thulium

168.9

103

Lw

Lawrencium

(262)

134

Uub

Ununbium

(302)

52

Te

Tellurium

127.6

70

Yb

Ytterbium

173.0

104

Fl

Flerovium

(289)

135

Uut

Ununtrium

(303)

53

I

Iodine

126.9

71

Lu

Lutetium

175.0

105

Uuq

Ununquadium

(303)

136

Uub

Ununbium

(303)

54

Xe

Xenon

131.8

72

Uuq

Ununquadium

(303)

106

Uut

Ununtrium

(304)

137

Uuq

Ununquadium

(304)

55

Cs

Cesium

132.9

73

Uuq

Ununquadium

(304)

107

Uub

Ununbium

(304)

138

Uut

Ununtrium

(305)

56

Ba

Barium

137.3

74

Uuq

Ununquadium

(304)

108

Uut

Ununtrium

(305)

139

Uuq

Ununquadium

(305)

57

La

Lanthanum

138.9

75

Uuq

Ununquadium

(305)

109

Uub

Ununbium

(305)

140

Uut

Ununtrium

(306)

58

Ce

Cerium

140.1

76

Uuq

Ununquadium

(305)

110

Uut

Ununtrium

(306)

141

Uuq

Ununquadium

(306)

59

Pr

Praseodymium

140.9

77

Uuq

Ununquadium

(306)

111

Uub

Ununbium

(306)

142

Uut

Ununtrium

(307)

60

Nd

Neodymium

144.2

78

Uuq

Ununquadium

(306)

112

Uut

Ununtrium

(307)

143

Uuq

Ununquadium

(307)

61

Pm

Promethium

(145)

79

Uuq

Ununquadium

(307)

113

Uub

Ununbium

(307)

144

Uut

Ununtrium

(308)

62

Sm

Samarium

150.4

80

Uuq

Ununquadium

(307)

114

Uut

Ununtrium

(308)

145

Uuq

Ununquadium

(308)

63

Eu

Europium

152.0

81

Uuq

Ununquadium

(308)

115

Uub

Ununbium

(308)

146

Uut

Ununtrium

(309)

64

Gd

Gadolinium

157.3

82

Uuq

Ununquadium

(308)

116

Uut

Ununtrium

(309)

147

Uuq

Ununquadium

(309)

65

Tb

Terbium

158.9

83

Uuq

Ununquadium

(309)

117

Uub

Ununbium

(309)

148

Uut

Ununtrium

(310)

66

Dy

Dysprosium

162.5

84

Uuq

Ununquadium

(309)

118

Uut

Ununtrium

(310)

149

Uuq

Ununquadium

(310)

67

Ho

Holmium

164.9

85

Uuq

Ununquadium

(309)

119

Uub

Ununbium

(310)

150

Uut

Ununtrium

(311)

68

Er

Erbium

167.3

86

Uuq

Ununquadium

(310)

120

Uut

Ununtrium

(311)

151

Uuq

Ununquadium

(311)

69

Tm

Thulium

168.9

87

Uuq

Ununquadium

(310)

121

Uub

Ununbium

(311)

152

Uut

Ununtrium

(312)

70

Yb

Ytterbium

173.0

88

Uuq

Ununquadium

(311)

122

Uut

Ununtrium

(312)

153

Uuq

Ununquadium

(312)

71

Lu

Lutetium

175.0

89

Uuq

Ununquadium

(311)

123

Uub

Ununbium

(312)

154

Uut

Ununtrium

(313)

72

Uuq

Ununquadium

(312)

90

Th

Thorium

232.0

124

Uub

Ununbium

(313)

155

Uut

Ununtrium

(314)

73

Uuq

Ununquadium

(313)

91

Pa

Protactinium

231.0

125

Uut

Ununtrium

(314)

156

Uuq

Ununquadium

(314)

74

Uuq

Ununquadium

(313)

92

U

Uranium

238.0

126

Uut

Ununtrium

(315)

157

Uuq

Ununquadium

(315)

75

Uuq

Ununquadium

(314)

93

Np

Neptunium

(237)

127

Uub

Ununbium

(315)

158

Uut

Ununtrium

(316)

76

Uuq

Ununquadium

(314)

94

Pu

Plutonium

(244)

128

Uut

Ununtrium

(316)

159

Uuq

Ununquadium

(316)

77

Uuq

Ununquadium

(315)

95

Am

Americium

(243)

129

Uub

Ununbium

(316)

160

Uut

Ununtrium

(317)

78

Uuq

Ununquadium

(315)

96

Cm

Curium

(247)

130

Uut

Ununtrium

(317)

161

Uuq

Ununquadium

(317)

79

Uuq

Ununquadium

(316)

97

Bk

Berkelium

(247)

131

Uub

Ununbium

(317)

162

Uut

Ununtrium

(318)

80

Uuq

Ununquadium

(316)

98

Cf

Californium

(251)

132

Uut

Ununtrium

(318)

163

Uuq

Ununquadium

(318)

81

Uuq

Ununquadium

(317)

99

Es

Einsteinium

(252)

133

Uub

Ununbium

(318)

164

Uut

Ununtrium

(319)

82

Uuq

Ununquadium

(317)

100

Fm

Fermium

(257)

134

Uut

Ununtrium

(319)

165

Uuq

Ununquadium

(319)

83

Uuq

Ununquadium

(318)

101

Md

Mendelevium

(260)

135

Uub

Ununbium

(319)

166

Uut

Ununtrium

(320)

84

Uuq

Ununquadium

(318)

102

No

Nobelium

(259)

136

Uut

Ununtrium

(320)

167

Uuq

Ununquadium

(320)

85

Uuq

Ununquadium

(319)

103

Lw

Lawrencium

(262)

137

Uub

Ununbium

(320)

168

Uut

Ununtrium

(321)

86

Uuq

Ununquadium

(319)

104

Fl

Flerovium

(289)

138

Uut

Ununtrium

(321)

169

Uuq

Ununquadium

(321)

87

Uuq

Ununquadium

(320)

105

Uuq

Ununquadium

(320)

139

Uub

Ununbium

(321)

170

Uut

Ununtrium

(322)

88

Uuq

Ununquadium

(320)

106

Uuq

Ununquadium

(321)

140

Uut

Ununtrium

(322)

171

Uuq

Ununquadium

(322)

89

Uuq

Ununquadium

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107

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Ununquadium

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Uut

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Th

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Uuq

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Uub

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