High Definition and Digital Television

J. Brinkley, *Defining Vision: The Battle for the Future of Television* (New York: Harcourt Brace, 1997).

N. Negroponte, *Being Digital* (New York: Knopf, 1995).

CHAPTER 13. PROBING THE ATOM

Suggested Mini-Laboratory Exploration

- How Do We Know That Atoms Really Exist? The Brownianscope.

Suggested Major Laboratory Exploration

- Avogadro's Number and the Size and Mass of a Molecule.

Demonstration

The effect of a magnetic field on an electron beam can easily be demonstrated by moving a bar magnet slowly toward the stationary beam of an oscilloscope or toward a television or computer monitor displaying a still image. Students are usually astonished that the beam moves perpendicularly to the direction of increasing field intensity. The direction can be predicted using the Lorentz force.

Objectives

This chapter is the first of three chapters that follow the journey inward toward an understanding of the atomic realm. While the first half of this text culminated in relativity theory, this half of the text turns toward atoms, the corresponding contemporary theory of their behavior—quantum mechanics, and areas of physics that have emerged from this work.

Suggestions

Review the material on the electromagnetic spectrum in Section 12.5, pointing out the position of X rays on the spectrum, as well as the change in damaging effects of electromagnetic waves as the frequency increases above the visible range.

The laboratory on Avogardro's number should be preceded by a considerable review of the arithmetic operations using scientific notation.

Further Reading

A.B. Arons, *A Guide to Introductory Physics Teaching* (New York: Wiley, 1990), Chapter 10.

G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapters 20, 21, 26.

B.H. Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (Piscataway, NJ: Rutgers University Press, 1996).

C.E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook* (Woodbury, NY: AIP Press, 1997), Chapter 21.

Web site

"The Discovery of the Electron": http://www.aip.org/history/electron

Technology and Medical Imaging: Further Information and Points for Study

Sloan Technology Series Source

B. H. Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (Piscataway, NJ: Rutgers University Press, 1996).

The Dangerous Costs of X Rays

The public attitude toward science and technology at the turn of the century contained interesting contradictions. On the one hand, the optimistic spirit of *fin de siècle* incorporated a celebration of the scientific and technological developments of the previous decade. However, among other segments of the population, there was an equally pervasive feeling that the industrial revolution had been a dehumanizing experience, and those recent technological advances were threatening to intellectual and material culture.

These conflicting views, concerning the benefits of technology, were nowhere more apparent than in the development of X rays. For this new discovery promised to uncover diseases previously hidden from the physicians' gaze, whilst itself, also harboring hidden dangers of exposure to radiation. To complicate the discussion, the benefits of X rays for medical procedures were evident from the very beginning, and the burns that sometimes occurred after long exposure did not outweigh the benefits. It was years before the full extent of side effects would manifest themselves in the form of cancers in those too heavily radiated, including the physicians. It is poignant, that Edison, as one of the most ardent supporters of X ray technology in its early years, became one of the first to turn his back on X rays, as he came to believe that the benefits did not outweigh the costs.

Eventually sufficient shielding with lead was developed, which helped to reduce the risks faced by the physicians.

This medical and public discourse on the side effects of X rays carried over into debates concerning the various medical imaging technologies that emerged throughout the twentieth century. The same cost–benefit analysis was applied to the danger of radiation from X rays in the first half of the century, and the possible effects of the magnetic fields of Positron Emission Tomography in the second half.

How Art and Literature Responded to Roentgen's Discovery

The influence of X rays on the broader intellectual culture at the turn of the century, in particular, art, poetry, and literature, was pervasive. Artists were confronted with new images of the human body, which they reacted to, and took in as part of their frames of reference. This is particularly apparent in the cubist tradition that emerged in the first few years of the twentieth century. H.G. Wells became one of the first to incorporate the myths that were growing around X rays, in his story *The Invisible Man* (1897); although he reversed the principle, so that X rays would cause humans to become invisible rather than visible. In Thomas Mann's *Magic Mountain* (1924), Hans Castorp is X rayed, to examine his tubercular lung. In 1939, Hollywood took hold of the theme, creating Superman with "X-ray vision."

Implications for Gender Debates

Throughout the century, medical imaging technologies have also had implications for gender debates. The discovery of X rays at the end of the nineteenth century gave the male dominated medical profession access' and control over, previously hidden parts of the woman's body. However, there is also a convincing argument that says X rays reduced the male and female body to the same collection of bones, without the traditional differentiating features, such as breasts. Another argument is that the new technology did not actually render visible what had not already been visible through surgery, dissection, and anatomical drawings, which had been integral parts of medical practice for centuries.

Questions concerning the woman's body in medical culture also arose during the development of mammograms and ultra-sound technology. In the case of ultra-sound, pregnant women could for the first time be seen to carry foetuses at various stages of development in their womb. Some people thought this challenged traditional conceptions of motherhood, and medicalized the treatment of the mother and baby even further, adding fuel to the debate over abortion.

Legal and Forensic Aspects of Medical Imaging

The use of X rays as a tool in medical diagnostics, provided, for the first time, a picture of a bullet in a patient's body, or an image of a broken ankle. Legal and forensic debates over the admissibility of these images in trials provide interesting arenas for examining the acceptance of imaging technologies, both inside the medical community, as well as the wider public.

Quotes Highlighting Important Issues

"Looking back, it is hard to understand how deeply opaque the world, and the human body, seemed to everyone before 1896. . . . This was a world where men and women wore several layers of clothing in all seasons . . . where full-length mirrors were a luxury, and few people ever saw, much less examined, their own naked bodies. Skeletons, which could be seen only after death, quite reasonably symbolized death. This era was drawing to a close in the mid-1890s, and the discovery of X rays was one of the nails in the coffin of Victorian prudery."[1]

George C. Johnston, president of the American Roentgen Ray Society, remonstrated in 1909 that: "the apparatus of today is obsolete tomorrow. There is a constant race between our pocketbooks and the inventive genius of the up-to-date manufacturer."[2]

" . . . as a civilisation, perhaps even as a species, we like to look, like to look through, and like to look at and through ourselves. In black and white and in color, in two-dimensional slices or in three-dimensional volumes, in frozen instants, or moving sequences, the X ray and its daughter technologies seem to satisfy an innate curiosity to see ourselves naked to the bone."[3]

Further Reading

Science and Technology of X Rays

E.H. Burrows, *Pioneers in the Early Years: A History of British Radiology* (Alderney, Channel Islands: Colophon, 1986).

A.B.Davis, *Medicine and its Technology: An Introduction to the History of Medical Instrumentation* (Westport, CT: Greenwood Press, 1981).

S. Quinn, *Marie Curie: A Life* (New York: Simon and Schuster, 1995).

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[1] B.H. Kevles, *Naked to the Bone*, p. 14.

[2] G.C. Johnston, President's Address, *Amer. Quart. Roentgenology* 2 (1909), 53–55. Quoted in B.H. Kevles, *Naked to the Bone*, p. 61.

[3] B.H. Kevles, *Naked to the Bone*, p. 302.

The Dangerous Costs of X Rays

P. Brown, *American Martyrs to Science through the Roentgen Rays* (Springfield, IL: University of Illinois, 1936), p. 11.

J.D. Nauman, Pioneer descriptions in the story of X ray protection, In: *Classic Descriptions in Diagnostic Roentgenology*, ed. A.D. Bruwer (Springfield, IL: University of Illinois, 1964), pp. 311–344.

D. Walsh, Deep tissue traumatization from Roentgen rays exposure, *British Medical J.* (1897), 272; reprinted in *Health Phys.* **38** (1980), 885–887.

Art and Literature

K. Alder and M. Pointon, eds., *The Body Imaged* (New York: Cambridge University Press, 1993).

C. Brinton, Evolution not revolution in art, *The International Studio*, **54**, no. 194 (April 1913).

A. Burroughs, *Art Criticism from a Laboratory* (Boston: Little Brown, 1938).

W.A. Camfield, *Francis Picabia: His Art, Life and Times* (Princeton, NJ: Princeton University Press, 1979).

D. Cooper, *The Cubist Epoch* (New York: Metropolitan Museum of Art and Phaidon Press, 1970).

J. Crary, *On Vision and Modernity in the Nineteenth Century* (Cambridge, MA: MIT Press, 1990).

J.H. Gardiner, The origins, history and development of the X ray tube, In: *Classic Descriptions in Diagnostic Roentgenology*, ed. A.J. Bruwer (Springfield, IL: University of Illinois, 1964).

T. Mann, *The Magic Mountain* (New York: Knopf, 1925).

Women and Medical Imaging

B. Duden, *Disembodying Women: Perspectives on Pregnancy and the Unborn* (Cambridge, MA: Harvard University Press, 1993).

A. Oakley, *The Captured Womb: A History of the Medical Care of Women* (Oxford, UK: Blackwell, 1984).

Legal and Forensic

V.P. Collins, Origins of medico–legal and forensic roentgenology, In: *Classic Descriptions in Diagnostic Roenigenology*, ed. A.J. Bruwer (Springfield, IL: University of Illinois, 1964), pp. 1578–1604.

W.G. Eckert, The history of forensic applications in forensic radiology, *Amer. J. Forensic Medicine and Pathology*, **5**, (1984), 53–56.

K.T. Evans and B. Knight, *Forensic Radiology* (Oxford, UK: Blackwell, 1981).

E.A. James, ed., *Medical/Legal Issues for Radiologists* (Chicago: Precept Press, 1987).

Daughter Technologies

L. Bassett, R.H. Gold, and C. Kinmie-Smith, "History of the Technical Development of Mammography," RSNA Categorical Course in Physics, 1993.

G.D. Dodd and RH. Gold, The history of mammography, In: *Radiology Centennial Volume* (New York: American College of Radiology, 1996).

B. Goldberg and B. Kinimelman, *Medical Diagnostic Ultrasound: A Retrospective on its 40th Anniversary* (New York: Eastman Kodak, 1988).

Politics

W.F. Manges, Military roentgenology, In: *The Science of Radiology*, ed. O. Glasser (Springfield, IL: University of Illinois, 1933).

Economic and Technological Change

S.S. Blume, *Insight and Industry: On the Dynamics of Technological Change in Medicine* (Cambridge, MA: MIT Press, 1992).

CHAPTER 14. A QUANTUM MODEL OF THE ATOM

Suggested Mini-Laboratory Explorations

- Spectroscopy.
- Our Place in Space, especially the exercise in constructing a scale model of the hydrogen atom.
- Light and Color.

Project Physics Classic Video

"Rutherford Scattering". Available in VHS and DVD formats with new audio track and sound effects, *Physics: Cinema Classics* (Lexington, KY: Ztek Co.): http://www.ztek.com.

Objectives

The material in this chapter and in the previous one is presented as a detective story leading to an understanding of the structure of the atom. These chapters convey both the exciting trail of research and the experimental basis of each clue along the way.

We have attempted to ground as much of the material as possible in the empirical evidence. In fact, part of the "mystery" was to account for the empirical evidence, such as regularities in spectroscopy, the Balmer formula, and the stability of atoms, that had been mounting for many years. Students should appreciate the inability of classical physics to account for these phenomena, and thus the need for a new theory. They should also appreciate the revolutionary nature of the quantum idea, as Einstein put it, in the previous chapter, and the problematic yet tantalizingly successful Bohr model of

the atom, presented in this chapter. These provide good examples of the struggle of modern physics to understand new phenomena, when the available conceptual apparatus for understanding appears inadequate to the task.

Suggestions

Before beginning, review the Periodic Table, as presented in the previous chapter. Remind students of the meaning of atomic number and atomic mass.

Further Reading

A.B. Arons, *A Guide to Introductory Physics Teaching* (New York: Wiley, 1990), Section 10.11.

G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapter 28.

C.E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook* (Woodbury, NY: AIP Press, 1997), Chapter 21.

CHAPTER 15. QUANTUM MECHANICS

Web sites

"Heisenberg and the Uncertainty Principle": http://www.aip.org/history/heisenberg
Double slit experiment with individual particles: http://inkey.com/dslit

Objectives and Suggestions for Achieving Them

In this chapter we present the basic ideas and implications of quantum mechanics, along with the experimental evidence and reasoning that led to these ideas. Students will find many of these ideas strange and even disconcerting. Some may resist their acceptance, just as many physicists did and continue to do. Students should be reassured that their discomfort is well founded and shared by many others. The current interpretation is still controversial and the theory itself may undergo significant changes in the future. However, as with all theories, it is the best understanding that we can achieve at present on the basis of our study of the experimental evidence. The main purpose is not to convince students that these ideas are the correct ones, but to describe our current understanding of the reasons why we currently accept this interpretation.

Although we refer briefly to alternative interpretations, we have not provided any discussion here of some of the currently viable proposals, in the interest of focusing on the essentials. Students and instructors who are in-

terested in further exploring these ideas or some of the proposed alternative interpretations are referred to the further reading.

Further Reading

A large body of literature on quantum mechanics for the general educated public has arisen in recent years. Some of these works emphasize applications to specific fields, such as particle physics or cosmology. Here is a brief list of some of the generally accessible works currently available, in alphabetical order.

D. Cassidy, *Uncertainty: The Life and Science of Werner Heisenberg* (New York: Freeman, 1992).

R. Crease et al., *The Second Generation: Makers of the Revolution in Twentieth Century Physics* (Piscataway, NJ: Rutgers University Press, 1986).

R.P. Feynman, *Six Easy Pieces* (Reading, MA: Perseus, 1995), Chapter 6.

R.P. Feynman, *QED: The Strange Theory of Light and Matter* (Princeton, NJ: Princeton University Press, 1985).

B. Greene, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (New York: Norton, 1999).

J. Gribbon, *In Search of Schrödinger's Cat, Quantum Physics, and Reality* (New York: Bantam, 1984).

R.M. Hazen with M. Singer, *Why Aren't Black Holes Black? The Unanswered Questions at the Frontiers of Science* (New York: Anchor/Doubleday, 1997).

A. Hobson, *Physics: Concepts and Connections*, 2nd ed. (Upper Saddle River: Prentice-Hall, 1999), Chapters 13, 14, 18.

G. Holton, Roots of complementarity, In: G. Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, MA: Harvard University Press, 1988), pp. 99–145.

G. Holton and S.G. Brush, *Physics, The Human Adventure* (Piscataway, NJ: Rutgers University Press, 2001), Chapter 29.

G. Kane, *The Particle Garden: Our Universe as Understood by a Particle Physicist* (Boston: Addison-Wesley, 1995).

H. Kragh, *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton, NJ: Princeton University Press, 1999).

L. Lederman with D. Teresi, *The God Particle* (New York: Dell, 1993).

D. Lindley, *Where Does the Weirdness Go? Why Quantum Mechanics Is Strange, But Not As Strange As You Might Think* (New York: Basic Books, 1996).

D. Schramm and L. Lederman, *From Quarks to the Cosmos: Tools of Discovery* (New York: Freeman, 1989).

C.H. Townes, *How the Laser Happened: Adventures of a Scientist* (New York: Oxford University Press, 1999).

D. Wick, *The Infamous Boundary: Seven Decades of Heresy in Quantum Physics* (New York: Springer-Verlag, 1996).

S. Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992).