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Introduction

As the end of nineteenth century approached, science was in a contented state. Man's understanding of space and time, matter and energy, and the basic physics principles appeared to be fundamentally correct. The basic physical laws were established. Newton's laws described the motion of objects, their interaction, and fundamental characteristics such as momentum and energy. Maxwell equations explained known electric and magnetic phenomena. Dalton's ideas revealed the atomic nature of matter, and Mendeleev devised a periodic system for chemical elements.

It was generally believed that the basic laws of the universe were known and that the essential interactions involving these laws had been determined. The remaining challenges involved filling in the details regarding the known interactions and fundamental laws. Little did mankind know that radical revisions to the nineteenth-century view would soon be required with the emergence of new physics, which coincided with the birth of health physics profession.

The discovery of X-rays by William's Röntgen in 1895 was an unexpected event. Röntgen's discovery initiated the birth of new science including the field of health physics, and signaled the first of many events that shook the foundation of nineteenth century physics. These events led to an improved view of matter and its interaction properties. For example, atomic energy levels were described by a series of improving models and theories; the nucleus, its energy levels, and interactions were revealed; an increasing, large set of fundamental particles was discovered and their number continued to grow; additional radiation types were found and their interactions characterized and quantified.

Although Maxwell equations survived, the new physics replaced most of the nineteenth century physics. The new physics was satisfactorily described through quantum mechanics, quantum electrodynamics, special and general relativity, the nuclear shell model, nuclear optical models, and the Standard Model of Particle Physics.

Although Röntgen's discovery of X-rays was the genesis for the health physics field, the Manhattan Project cemented health physics as a profession. Other events such as the Hiroshima and Nagasaki atomic bomb attacks, weapons production activities, development of nuclear fission technology, medical and industrial applications of radioisotopes, manned space missions, nuclear fusion studies, high-energy accelerator operation, and studies of the biological effects of ionizing radiation significantly

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influenced the health physics field. From these beginnings, the health physics field continued to grow.

The twentieth century saw a maturation of the health physics profession and its scientific basis. A standard set of units evolved and the various radiation types were characterized. National and international organizations were formed to foster sustained development and standardization. Instrumentation advances permitted the detection of a variety of ionizing radiation types over a wide range of energies.

A summary of the key events and dates associated with the physics and health physics professions is provided in Appendix A. Although the events selected for inclusion in Appendix A are somewhat subjective, they are representative of significant events influencing the development of the health physics profession.

The events of Appendix A will also influence the development of twenty-first century radiation generating technologies, and the associated development of health physics practices to protect workers from the radiation hazards of these technologies. Although the evolution of these technologies is uncertain, they will certainly involve energies and radiation types that will require careful management.

Health Physics in the 21st Century reviews emerging and maturing radiation generating technologies that will affect the health physics profession. It is hoped that this review will foster additional research into these areas and into areas not yet imagined.

Health physics is a dynamic and vital field and has an exciting future. However, significant challenges will likely arise as new physics emerges, new particles and radiation types are discovered, and old paradigms fall. For example, the Standard Model will be superseded, as was Classical Mechanics, and be replaced by an improved theory. It is unclear what theories will emerge, but the diversity of current approaches (e.g., supersymmetry, quantum gravity, twistor theory, string theory, grand unification theories, and higher dimensional theories) offer insight into an exciting future.

There is an intimate linkage between the health physics profession and emerging physics. New physics produces new energy regimes that lead to the production of a diversity of radiation types. In some cases, the magnitude of known hazards will increase, but new hazards may also emerge. For example, neutrinos do not present a significant hazard at light water reactors or twentieth-century accelerators. However, when accelerator energies reach the PeV energy range or when the particle fluences significantly increase, neutrino effective doses can no longer be ignored.

Although a large number of emerging radiation generating technologies exist, it is practical to only consider a representative subset. The following are judged by the author to be representative of future health physics challenges and these are further explored in this book:

- Generation III and IV fission reactors
- Fusion power facilities
- High-energy accelerators including muon colliders
- Photon light sources including free electron lasers

- Manned planetary missions
- Deep space missions
- Advanced nuclear fuel cycles including laser isotope separation and actinide transmutation
- Radiation therapy using heavy ions, exotic particles, and antimatter
- Radioactive dispersal devices and improvised nuclear devices
- Evolving regulatory considerations

The first six of these listed topics are covered in Volume I of *Health Physics in the 21st Century*. The remaining topics and additional areas are the subject of Volume II.

The twenty-first century should be an exciting time for the health physics profession. It is the author's desire that this book contributes in some small measure to the education of twenty-first century health physicists and their understanding of emerging radiation generating technologies. The author also hopes that this book will foster additional effort to improve upon and further develop the topics covered in this book and additional emerging areas.

Good luck and best wishes in advancing our proud profession.

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