Table of Contents

UNCORRECTED PROOF

Preface xiii

Acknowledgments xv

Chapter 1. Introduction to Health Physics 1
1.1 Definition of Health Physics 1
1.2 Overview of the Role of Health Physics 1
1.3 Employment of Health Physicists 2
1.4 Educational Background 2
1.5 Interaction of Health Physicists with Other Disciplines 3
1.6 This Text and its Relation to a Training Program 4

Chapter 2. Scientific Fundamentals 5
2.1 Quantities and Units in Science and Engineering 5
2.2 Background Information 6
2.3 Nature of Matter—Molecules, Atoms, Quarks 7
2.4 Excitation and Ionization 10
2.5 Refinements to the Bohr Atom 11
2.6 Characteristic X-rays 12
2.7 Binding Energy 13
2.8 The Chart of the Nuclides 14
2.9 Some Elements of Quantum Theory 15
2.9.1 Electromagnetic Radiation 15
2.9.2 Wave/Particle Duality of Nature 17
2.9.3 The Heisenberg Uncertainty Principle 17

Chapter 3. Radioactive Atoms—Nature and Behavior 18
3.1 Alpha Emission 21
3.2 Positron Emission 23
3.3 Orbital Electron Capture 25
3.4 Beta (Minus) Emission 26
3.5 Gamma Ray Emission 27
3.6 Internal Conversion Electrons 28
3.7 Auger Electrons 28
3.8 Summary and Examples 28
3.9 Transformation Kinetics 30
3.10 Average Life (Mean Life) 34

3.11 Specific Activity 34
3.12 Series Decay 35
3.13 Time of Maximum Progeny Activity 38
3.14 Tracing Radioactive Decay on the Chart of the Nuclides 40

Chapter 4. Interaction of Radiation with Matter 43
4.1 Charged Particle Interaction Mechanisms 46
4.2 Alpha Particle Interactions 46
4.3 Beta Particle Interactions 49
4.4 Specific Ionization 52
4.5 Mass Stopping Power 53
4.6 Linear Energy Transfer (LET) 54
4.7 Bremsstrahlung Radiation 54
4.8 Gamma Ray Interactions 55
4.9 Mechanisms 57
4.9.1 Photoelectric Effect 58
4.9.2 Compton Effect 58
4.9.3 Pair Production 60
4.9.4 Photodisintegration 60
4.10 Photon Attenuation and Absorption Coefficients 61
4.11 Neutron Interactions 61
4.11.1 Scattering 64
4.11.2 Absorption 64

Chapter 5. Quantities and Units in Radiation Protection 67
5.1 Exposure 69
5.2 Absorbed Dose and Equivalent Dose 69
5.3 Radioactivity 73
5.4 Particle and Energy Field Units 74

Chapter 6. Biological Effects of Radiation 75
6.1 Introduction: Background 75
6.2 Mechanisms of Radiation Damage to Biological Systems 79
6.3 Biological Effects in Humans 81
6.3.1 Nonstochastic Effects 82
6.3.1.1 Death from Whole Body Exposure—The Acute Radiation Syndrome 84
6.3.1.1.1 Hemopoetic Syndrome 85
6.3.1.1.2 Gastrointestinal (GI) Syndrome 86
6.3.1.1.3 Central Nervous System (CNS) Syndrome 86
6.3.1.2 Damage to Skin 87
6.3.1.3 Gonads 90
6.3.1.4 Cataract Formation 91
6.3.2 Stochastic Effects 92
6.3.2.1 Cancer 92
6.3.2.2 Leukemia 95
6.3.2.3 Bone Cancer 95
6.3.2.4 Lung Cancer 95
6.3.2.5 Thyroid Cancer 97

UNCORRECTED PROOF

6.3.2.6 Hereditary Effects 98
6.3.2.7 Mathematical Models of Cancer Risk 98
6.4 Cell Survival Studies 100
6.5 Relative Biological Effectiveness 102

Chapter 7. The Basis for Regulation of Radiation Exposure 105
7.1 Period 1: 1895–1913 105
7.2 Period 2: 1913–1922 105
7.3 Period 3: 1922–1928 106
7.4 Period 4: 1928–1934 106
7.5 Period 5: 1934–1941 107
7.6 Period 6: 1941–1946 107
7.7 Period 7: 1946–1953 108
7.8 Period 8: 1953–1959 109
7.9 Period 9: 1960–1965 110
7.10 Period 10: 1966–Present 111
7.11 Period 11: The Future 114
7.12 Radiation Regulations—An Acronym-Onious History 115
7.12.1 Introduction 115
7.12.2 Scientific Advisory Bodies 116
7.12.3 Regulatory Bodies 119

Chapter 8. Health Physics Instrumentation 132
8.1 Thermal Reactions 132
8.2 Chemical Reactions 133
8.3 Electrical Devices 134
8.3.1 Gas Filled Detectors 134
8.3.2 Light Production: Scintillation Detectors 145
8.3.3 Semiconductor Detectors 149
8.4 Alpha and Gamma Spectroscopy/Spectrometry 151
8.5 Personnel Monitoring 154
8.6 Neutron Detection 159
8.7 Calibration Considerations 162
8.7.1 Photons 163
8.7.2 Electrons/Beta 163
8.7.3 Alpha 163
8.7.4 Neutrons 164
8.8 Counting Statistics 164
8.8.1 Gaussian Distribution 165
8.8.2 Poisson Distribution 168
8.8.3 Propagation of Errors 170
8.8.4 Mean Value of Multiple Independent Counts 172
8.8.5 Minimum Detectable Activity 173
8.8.6 Optimization of Limited Counting Time 176

Chapter 9. External Dose Assessment 178
9.1 Dose from Discrete Photon Sources 179
9.2 Specific Gamma Ray Emission Factor 180
9.2.1 Point Source 180
9.2.2 Line Source 182

UNCORRECTED PROOF

9.2.3 Plane Source 183
9.2.4 Volume Source 184
9.3 Dose from Discrete Electron Sources 186
9.4 Hot Particles 188
9.5 Dose from Discrete Neutron Sources 189
9.6 Dose from Extended Sources 191
9.7 Tritium and Noble Gases 196
9.8 Computer Modeling in External Dose Assessment 198
9.9 Literature Resources in External Dose Assessment 202

Chapter 10. Internal Dose Assessment 205
10.1 Basic Concepts in Internal Dose Calculations 205
10.2 Effective Half-Time 207
10.3 Dosimetry Systems 209
10.3.1 Marinelli–Quimby Method 210
10.3.2 International Commission on Radiological Protection 210
10.3.3 MIRD System 212
10.3.4 RADAR 213
10.4 Internal Dose Calculations for Radiation Workers 213
10.5 Internal Dose Calculations for Nuclear Medicine Patients 228

Chapter 11. Radiation Protection Practice/Evaluation 244
11.1 Introduction 244
11.2 External Protection Principles 246
11.3 Shielding of Photon Sources 247
11.4 Graded or Laminated Shielding 250
11.5 Shielding of X-Ray Sources 251
11.6 Shielding of Discrete Electron Sources 257
11.7 Shielding of Neutron Sources 261
11.8 Performing Radiation Surveys 265
11.9 Principles of Optimization 266
11.10 Protection of Workers from Internal Contamination 269
11.11 Air Sampling Calculations 275
11.12 Methods for Gathering Bioassay Data 281
11.12.1 In-Vivo Counting 282
11.12.2 In-vitro Measurements 285
11.12.3 Interpretation of Bioassay Data 285
11.13 Criticality and Criticality Control 291

Chapter 12. Environmental Monitoring for Radiation 309
12.1 Types of Environmental Assessment Programs 310
12.2 Types of Facilities Monitored 311
12.3 Types of Samples and Sampling Strategies 311
12.3.1 Direct Gamma Exposure Readings 313
12.3.2 Airborne Concentrations of Radionuclides 315
12.4 Long-Term Off-Site Monitoring 316
12.4.1 Concentrations of Radionuclides in Water 318
12.4.2 Concentrations of Radionuclides in Soil or Sediment 320
12.4.3 Concentrations of Radionuclides in Biological Species (Biota) 322
12.5 General Sampling Strategies and Techniques 323

UNCORRECTED PROOF

12.6 Sample Management 326
12.7 Instrumentation 329
12.8 Evaluation of the Data 330
12.9 Radioactive Waste Management 336
12.9.1 The Nuclear Fuel Cycle 336
12.9.2 General Waste Types 340
12.10 Site Evaluation 343

Chapter 13. Nonionizing Radiation 347
13.1 Ultraviolet Radiation 347
13.2 Lasers 352
13.3 Radiofrequency Radiation, and Microwave Sources 362
13.4 EMF 367
13.5 Magnetic Resonance Imaging (MRI) 368

Index 373

UNCORRECTED PROOF