

Contents

Preface — vii

Acknowledgments — ix

Part A: Radiography

1	X-ray generation — 3
1.1	Introduction — 3
1.2	X-ray production — 4
1.2.1	Bremsstrahlung — 4
1.2.2	Characteristic radiation — 6
1.2.3	Characteristic x-ray energies — 8
1.2.4	Energy dispersive x-ray chemical analysis — 9
1.2.5	Final remarks — 10
1.3	X-ray generators — 10
1.3.1	X-ray tubes — 10
1.3.2	Linear accelerators — 13
1.3.3	Synchrotron radiation — 15
1.4	Summary — 17
2	Nuclei and isotopes — 19
2.1	Introduction — 19
2.2	Isotopes — 20
2.3	Atomic mass and atomic weight — 22
2.4	Nuclear decay — 23
2.4.1	Electron emission (β^-) — 23
2.4.2	Positron emission (β^+) — 24
2.4.3	Electron capture (EC) — 25
2.4.4	Alpha decay — 25
2.4.5	Decay schemes — 26
2.5	Radioactivity — 28
2.5.1	Exponential decay law — 28
2.5.2	Nuclear activity — 30
2.5.3	Decay chains — 31
2.6	Production of radioisotopes — 32
2.6.1	Nuclear reactions — 32
2.6.2	Cyclotron generation of isotopes — 34

2.6.3	Radioisotope production by fission —	37
2.6.4	Neutron activation —	39
2.7	Summary —	41
3	Interaction of radiation with matter —	42
3.1	Introduction —	42
3.2	Interaction of EM radiation with matter —	43
3.2.1	Mass attenuation coefficient —	43
3.2.2	Coherent scattering —	44
3.2.3	Photoelectric effect —	45
3.2.4	Compton effect —	48
3.2.5	Pair production —	49
3.2.6	Comparison of photon-electron interactions —	49
3.3	Interaction of charged particles with matter —	50
3.3.1	Alpha particles —	50
3.3.2	Beta particles —	53
3.4	Interaction of neutrons with matter —	54
3.5	Summary —	57
4	Radiation detection and protection —	59
4.1	Introduction —	59
4.2	Definitions of dose —	59
4.3	Energy fluence and kerma —	62
4.4	Dosimeters —	64
4.5	Radiation exposure —	67
4.6	Radiation protection —	69
4.7	Summary —	70
5	X-ray radiography —	71
5.1	Introduction —	71
5.2	Image formation —	71
5.2.1	Attenuation contrast —	71
5.2.2	Beam hardening —	75
5.2.3	X-ray films —	76
5.2.4	Digital recording —	78
5.2.5	System integration —	79
5.3	Contrast enhancement —	81
5.3.1	Contrast agents —	81
5.3.2	Digital subtraction angiography (DSA) —	82
5.3.3	Dual x-ray energy imaging (DXE) —	83
5.3.4	Phase contrast imaging —	84
5.4	Computed tomography (CT) —	87

5.5	Risks and comparisons —	93
5.6	Summary —	94
6	Scintigraphy —	97
6.1	Introduction —	97
6.2	Isotopes for scintigraphy —	98
6.3	Isotope generators —	99
6.4	Recording of scintigrams —	100
6.5	Single photon emission computed tomography (SPECT) —	103
6.6	Summary —	106
7	Positron emission tomography —	108
7.1	Introduction —	108
7.2	Basic principle of PET —	108
7.3	Isotopes for PET —	112
7.4	Use of F-18 in PET scans —	113
7.5	Summary —	116

Part B: Radiotherapy

8	Cell cycle and cancer —	121
8.1	Introduction —	121
8.2	Life cycle of cells —	121
8.3	Cancerous cells —	124
8.4	Radiation response of cells —	128
8.4.1	Cell response to radiation —	128
8.4.2	Fractionation —	129
8.4.3	Biological effect of radiation —	130
8.4.4	Relative biological effectiveness (RBE) —	131
8.4.5	Radiation treatment plan —	133
8.4.6	Hypoxia and chemotherapy —	134
8.5	Summary —	135
9	X-ray radiotherapy —	138
9.1	Introduction —	138
9.2	Radiation treatment planning —	139
9.3	Absorbed dose by high energy photon beam —	140
9.3.1	Depth-dose profiles —	141
9.3.2	Dose to isocenter —	144
9.4	Target volume —	145
9.5	Multileaf collimator and intensity modulated radiotherapy —	147

9.6 Linear accelerators for x-ray generation — 151

9.7 Cyberknife technology — 153

9.8 Gamma knife — 155

9.9 Summary — 156

10 Charged particle radiotherapy — 158

10.1 Introduction — 158

10.2 Range of protons in tissue — 159

10.3 Dose profiles of charged particles — 161

10.4 Examples for proton beam therapy — 164

10.5 Carbon ion beam therapy — 167

10.6 Accelerators and gantries for proton beam therapy — 169

10.7 Summary — 170

11 Neutron radiotherapy — 173

11.1 Introduction — 173

11.2 Neutrons and neutron production — 174

11.2.1 Neutron energies — 174

11.2.2 Fast neutrons from fission — 175

11.2.3 Accelerator-based neutron sources — 176

11.2.4 Accelerator facility — 178

11.3 Linear energy transfer for fast neutrons — 179

11.4 Boron neutron capture therapy — 181

11.5 Summary — 183

12 Brachytherapy — 185

12.1 Introduction — 185

12.2 Radioisotopes for brachytherapy — 186

12.2.1 General considerations — 186

12.2.2 Radioisotope ^{137}Cs — 187

12.2.3 Radioisotope ^{60}Co — 188

12.2.4 Radioisotope ^{192}Ir — 189

12.2.5 Radioisotope ^{125}I — 189

12.2.6 Radioisotope ^{103}Pd — 190

12.2.7 Radioisotopes ^{198}Au and ^{106}Ru — 190

12.2.8 Radioisotope ^{90}Sr — 191

12.3 Procedures — 191

12.3.1 Interstitial and contact brachytherapy — 191

12.3.2 Cervical cancer — 192

12.3.3 Prostate cancer — 194

12.3.4 Breast cancer — 194

- 12.4 Dosimetry — 195
- 12.5 Summary — 197

Part C: Diagnostics and therapeutics beyond radiology

- 13 Laser applications in medicine — 201**
 - 13.1 Introduction — 201
 - 13.2 Laser basics — 203
 - 13.2.1 Two level system — 203
 - 13.2.2 Three level system — 204
 - 13.2.3 Basic components of lasers — 205
 - 13.2.4 YAG laser — 206
 - 13.2.5 Laser types, wavelengths, and units — 208
 - 13.3 Laser pulsation — 210
 - 13.3.1 Mechanical switching — 210
 - 13.3.2 Q switch — 210
 - 13.3.3 Mode locking — 212
 - 13.4 Laser interaction with tissue — 214
 - 13.4.1 Overview — 214
 - 13.4.2 Photothermal interaction — 217
 - 13.4.3 Photoablation — 218
 - 13.4.4 Plasma-induced ablation — 219
 - 13.4.5 Photomechanical interaction — 219
 - 13.4.6 Photochemical interaction — 220
 - 13.5 Laser applications in ophthalmology — 222
 - 13.5.1 Photorefractive keratectomy (PRK) — 222
 - 13.5.2 Diabetic retinopathy — 225
 - 13.5.3 Cataract and glaucoma — 226
 - 13.6 Summary — 228
- 14 Nanoparticles for nanomedical applications — 230**
 - 14.1 Introduction — 230
 - 14.2 Pathway of nanoparticles through the body — 232
 - 14.2.1 Reticuloendothelial system (RES) — 232
 - 14.2.2 Clearance — 232
 - 14.2.3 Enhanced permeation and retention effect (EPR) — 233
 - 14.2.4 Coatings — 233
 - 14.2.5 Antigen-antibody — 234
 - 14.2.6 Targeting — 235
 - 14.2.7 Size — 236
 - 14.2.8 Biocompatibility — 236

14.3	Magnetic nanoparticles for diagnostics and therapeutics — 236
14.3.1	Ferromagnetism — 237
14.3.2	Superparamagnetism — 239
14.3.3	Blocking temperature — 241
14.3.4	MRI imaging contrast — 242
14.3.5	Magnetic hyperthermia — 246
14.3.6	Magnetomechanical cell destruction — 249
14.4	Metal nanoparticles for diagnostics and therapy — 251
14.4.1	X-ray imaging contrast — 251
14.4.2	Plasmon resonance — 253
14.4.3	Photothermal therapy — 256
14.4.4	Imaging — 257
14.4.5	Surface enhanced Raman scattering — 259
14.5	Multimodality of theranostic nanoparticles — 261
14.6	Summary — 262

15 Prosthetics — 266

15.1	Introduction — 266
15.2	Exoprostheses — 267
15.2.1	Lower limb prostheses — 267
15.2.2	Upper limb prostheses — 270
15.3	Endoprostheses of the joints — 273
15.3.1	Hip replacement — 273
15.3.2	Knee replacement — 279
15.4	Endoprostheses of the cardiovascular system — 281
15.5	Implants of the sensory system — 285
15.5.1	Middle ear implants — 285
15.5.2	Retina implants — 288
15.6	Summary — 291

16 Questions & answers — 294

List of acronyms used in this book — 317

Index — 323