Contents

PREFACE

CHAPTER: 3

3-1.1 3-1.2

3-1.3

3-2.1

3-2.2

CHAPTER 1	RADIOACTIVE-DECAY PROCESSES.
	1-1 Atomic Structure =
	1-2 Decay Rate and Activity
	1-3 Mass and Energy Equivalence 6
	1-4 Modes of Decay
	1-4.1 Beta (Negatron) Decay
	1-4.2 Electron-capture Decay 8
	1-4.3 Positron Decay
	1-4.4 Alpha Decay
	1-4.5 Isomeric Transition and Gamma Radiation 10
	1-4.6 Internal Conversion
	1-4.7 Competitive Modes of Decay
	1 4.7 Component of Modes of 2 conjust 1 1 1 1 1 1 1
	References
	Biolography
	Problems
CHAPTER 2	Nuclear Reactions
	2-1 Reaction Rates and Cross Sections
	2-2 Neutron Reactions
	2-2.1 Thermal-neutron (Capture) Reactions 17
	2-2.2 Fission
	2-2.3 High-energy Neutron Reactions
	2-3 Charged-particle Reactions
	2-4 Electromagnetic-radiation Reactions
	References 22
	References

Alpha-particle Energy

Alpha-particle Interactions and Range in Air . .

Alpha-particle Interactions and Range in Matter

Range of Other Heavy Charged Particles

Beta-particle and Electron Sources and Spectra.

Electron Interactions with Matter

23

2:3

24

24

24

25

27

30

31

31

33

		3-2.3 Electron Range in Matter	37
	3-3		41
			41
		3-3.2 Interaction of Electromagnetic Radiation with	
		Matter,	44
		3-3.3 Range of Electromagnetic Radiation in Matter	52
	2.4	· ·	54
	3-4	Neutrons	54
		3-4.1 Neutron Sources and Spectra	
		3-4.2 Neutron Interactions	55
		3-4.3 Neutron Diffusion	60
		3-4.4 Neutron Transmission	61
	Ref	erences	62
	Pro	blems	62
Current 4	D	NAME OF THE OFFICE OFFICE OFFICE OFFICE OFFICE OFFICE OFFICE OFFICE OFFI	64
CHAPTER 4		DIATION DETECTION SYSTEMS	
	4-1	Gas Detectors	65
		4-1.1 Gas Detection Mechanisms	65
		4-1.2 Ionization and Excitation of Gases	66
		4-1.3 Ionization Chambers	70
		4-1.4 Proportional Counters	74
		4-1.5 Geiger-Mueller Counters	77
	4-2	Semiconductor Detection	79
		4-2.1 Semiconductor Detection Mechanism	79
		4-2.2 Surface-barrier Detectors	81
		4-2.3 Lithium-drift Detectors	82
	4-3	Scintillation Detection	83
	4 -3	4-3.1 Scintillation Detection Mechanisms	83
			85
			87
		4-3.3 Inorganic-crystal (NaI) Detectors	
		4-3.4 Liquid Scintillation and Other Organic Detectors.	90
	4-4	Electronic Equipment for Radiation-counting Systems	92
		4-4.1 Detector-pulse Characteristics	92
		4-4.2 Discriminators	93
		4-4.3 Univibrators	97
		4-4.4 Scaler Circuits	98
		4-4.5 Counting-rate Meters	01
		4-4.6 Pulse-height Analysis	103
	4-5	•	
	• •	Detection Methods	06
	Ref	erences	
	Rih	liography	เกร
	Dio	blems	inc
	110	OBLIN	. 0
CHAPTER 5	RA	DIATION DETECTOR RESPONSE	110
	5-1	Statistical Fluctuation of Radioactive Decay	11
		- · · · · · · · · · · · · · · · · · · ·	11
			114
		5-1.3 Useful Statistical Formulas for Predicting	
		• 1.5	118
	5.3		12
	5-2	Zation in a zation of the same	12
		5 2:1 I omit Source and Cymratical 2 closes in the transfer	
		5-2.2 Geometry Factor	122

		5-2.3 Absorption Factor	123
		5-2.4 Scattering Factor	126
		5-3 Inherent Detector Parameters	128
		5-3.1 Resolving-power Factor	128
		5-3.2 Detector-efficiency Factor	131
		5-3.3 Detector system Stability Factor	133
		References	134
		Bibliography	135
		Problems	135
Chapter (RADIATION SAFETY	136
	-	6-1 Permissible Exposure Levels	137
		6-1.1 Radiation-dose Units	137
		6-1.2 Radiation Effect on Man	138
		6-1.3 Permissible Radiation Dose	140
		6-2 Calculation of Radiation Doses	141
		6-2.1 Doses from Electromagnetic Radiation	141
		6-2.2 Doses from Charged Particles	145
		6-2.3 Doses from Neutrons	146
		6-3 Protection Against Radiation from External Sources	148
		6-3.1 Radiation-monitoring Methods and Instruments	148
		6-3.2 Control of External Radiation Exposure	149
		6-3.3 Routine Surveys and Decontamination	147
		Procedures	150
		6-4 Protection Against Radiation from Ingested Sources	152
		6-4.1 Residence Times of Radioisotopes in the Body.	152
		6-4.2 Radiation-monitoring Methods and Instruments	154
		6-4.3 Waste-disposal Procedures	
		Deference	155
		References	155
		Bibliography	156
		Problems	156
Chapter	7	RADIOTRACING PRINCIPLES AND TECHNIQUES	. 157
			. 157
			. 158
			. 158
		7-2 Tracer Characteristics Peculiar to Radiotracers	. 160
			. 160
			. 163
		1	. 163
			. 164
			. 164
		7-3 Selection and Preparation of Radiotracers	. 165
		· · · · · · · · · · · · · · · · · · ·	. 165
		· · · · · · · · · · · · · · · · · · ·	
		• • • • • • • • • • • • • • • • • • • •	. 166
			. 166
			. 168
			. 169
			. 169
			. 171
		7-4.3 Calibration Samples and Standards	. 172

x CONTENTS

	7-5 Design and Analysis of Radiotracer Experiments	174
	7-5.1 Experiment Feasibility	174
	7-5.2 Sources and Propagation of Errors in	
	Radiotracer Experiments	174
	7-5.3 Radiotracer Experiment Precision and	
		177
		178
		179
	Problems	170
Creaman	D. D. D. Comp. A. C.	101
CHAPTER 8		181
		181
		181
,		182
		183
	8-1.4 Flow Rates	186
		205
		205
		208
		209
	8-3 Wear	210
		215
		215
		219
		221
		223
	Bibliography	225
	Problems	225
_		
Chapter 9	RADIOTRACER APPLICATIONS TO ENGINEERING RESEARCH.	228,
	9-1 Automating Data Accumulation	228
	9-2 Unit Operations Research	234
	9-3 Mathematical Models and Process Mechanisms	241
	9-4 Diffusion and Mass Transfer	246
	References	251
	Bibliography	252
	Problems	252
		232
CHAPTER 10	RADIOGAUGING PRINCIPLES AND TECHNIQUES	254
CHAITER TO	10-1 Radiogauge Characteristics	254
		233
	and the second s	255
	Response	
	10-1.2 Radiogauge Standardization and Calibration.	
	10-1.3 Radiogauge Accuracy	258
	10-1.4 Radiogauge Sensitivity	
	10-2 Static and Continuous Radiogauge Considerations	
	10-2.1 Characteristics of Static Radiogauges	
	10-2.2 Characteristics of Continuous Radiogauges	
	10-3 Radiogauge Design and Optimization	
•	10-3.1 Choice of Radiogauge Principle	

	10-3.2 Choice of Radioisotope	. 281		
	10-3.3 Choice of Detection System	. 282		
	References	. 285		
	Problems	. 286		
CHAPTER 11	Radiogauging with Charged Particles			
	11-1 Alpha-particle Gauging	287		
	11-1.1 Ion-gauge Principle	288		
	11-1.2 Energy Principles	291		
	11-1.3 Range Principles	292		
	11-1.4 Digitizing Mechanical Sensors	300		
	11-2 Beta-particle Gauging	302		
	11-2.1 Energy and Range Principles	302		
	11-2.2 Backscatter Principle	311		
	11-2.3 Forward-scatter Principle	319		
	References	322		
		323		
Chapter 12	RADIOGAUGING WITH ELECTROMAGNETIC RADIATION	325		
		325		
	12-1.1 Thickness Measurement	325		
	12-1.2 Fluid-level Measurement	328		
	12-1.3 Density Measurement	332		
		336		
	12-2 Scatter of High-energy Radiation	342		
	12-2.1 Thickness Measurement	343		
	12-2.2 Density Measurement	345		
	12-3 Resonant Absorption of Low-energy Radiation	358		
		361		
		367		
		368		
		368		
CHAPTER 13	RADIOGAUGING WITH NEUTRONS	370		
	13-1 Moderation and Absorption	370		
	13-1.1 Mathematical Treatment of Neutron			
	Transport	372		
	13-1.2 Measurement of Soil Water Content	377		
	13-1.3 Measurement of Salt Content in Aqueous			
	Solution	383		
	13-1.4 Oil-well Logging and Other Miscellaneous			
	Measurements	386		
	13-2 Neutron Reactions for Producing Characteristic			
	Gamma Rays	. 386		
	References	. 390		
	Bibliography	. 390		
	Problems	. 39		
Chapter 14	RADIOGRAPHY	. 392		
	14-1 Principles of Radiography	. 392		

xii CONTENTS

	14-2 14-3 14-4 Refer Probl	Density Thickness	397 401 404 406 407 409
APPENDIX A	GEN FLO	W	411
APPENDIX B	A PR RADI	INTER PROGRAMMER FOR RECORDING TRANSIENT DIGITAL ATION-COUNTING DATA	41.
LABORATO	RYE	XPERIMENTS	
Introductio	N TO T	HE LABORATORY EXPERIMENTS	419
		PERIMENTS	
	E.1	Geiger-Mueller Counter Characteristics and Statistical Aspects of Radiation Detection.	
	E.2	Detector-system Response I — External Parameters	426
	E.3	Detector-system Response II—Inherent Parameters	430
	E.4	Techniques for Preparation and Standardization of Radioactive Samples	433
	E.5	Radiation Safety	439
RADIOTRACIN	G EXP	ERIMENTS	
	E.6	Flow Measurement with Radiotracers	443
	E.7	A Radiotracer Technique for Particle-size Determination.	
	E.8	A Radiotracer Technique for Residence-time Determination.	
	E.9	A Radiotracer Technique for Frequency-response Determination.	
RADIOGAUGIN	NG EXE		2,00
	E.10	Beta-particle Transmission Radiogauges for Measuring Liquid-hydrocarbon Hydrogen Fractions	167
	E.11	Beta-particle Forward-scatter Radiogauges for	
	E.12	Measuring Two-component Gases	
	E.13	Gamma-ray Scatter Radiogauges for Measuring the Densities of Solids.	
	E.14	Characteristics of Continuous Radiogauges 4	173
RADIOGRAPH	EXPE	(F. 17	
	E.15	Radiography	175
INDEX	4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		77
			111