

EXPERIMENTS IN MODERN PHYSICS

Second Edition

Adrian C. Melissinos

UNIVERSITY OF ROCHESTER

Jim Napolitano

RENSSELAER POLYTECHNIC INSTITUTE



ACADEMIC PRESS

An Imprint of Elsevier

Amsterdam Boston London New York Oxford Paris San Diego
San Francisco Singapore Sydney Tokyo

Contents

Preface	xi	
Preface from the First Edition	xv	
1	<i>Experiments on Quantization</i>	1
1.1.	Introduction	1
1.2.	The Millikan Oil Drop Experiment	2
1.3.	The Frank–Hertz Experiment	10
1.4.	The Hydrogen Spectrum	20
1.5.	Experiment on the Hydrogen Spectrum	25
1.6.	The Spectra of Sodium and Mercury	33
2	<i>Electrons in Solids</i>	45
2.1.	Solid Materials and Band Structure	45
2.2.	Experiment on the Resistivity of Metals	54
2.3.	Experiment on the Hall Effect	63
2.4.	Semiconductors	71
2.5.	High T_c Superconductors	81
2.6.	References	88
3	<i>Electronics and Data Acquisition</i>	89
3.1.	Elements of Circuit Theory	89
3.2.	Basic Electronic Equipment	104
3.3.	Oscilloscopes and Digitizers	110
3.4.	Simple Measurements	116

3.5. Operational Amplifiers	119
3.6. Measurements of Johnson Noise	122
3.7. Chaos	133
3.8. Lock-In Detection	144
3.9. Computer Interfaces	147
— 3.10. References	150
4 Lasers	151
4.1. The Principle of Laser Operation	152
4.2. Properties of Laser Beams	156
4.3. The HeNe Laser	159
4.4. Measurement of the Transverse Beam Profile	164
4.5. The Michelson Interferometer	167
4.6. The Fabry–Perot Interferometer	172
5 Optics Experiments	179
5.1. Introduction	179
5.2. Diffraction from a Slit	180
5.3. Calculation of the Diffraction Pattern	185
5.4. Diffraction from a Circular Aperture	188
5.5. The Diffraction Grating	192
5.6. Fourier Optics	198
5.7. The Faraday Effect	201
5.8. Berry’s Phase	210
5.9. References	214
6 High-Resolution Spectroscopy	215
6.1. Introduction	215
6.2. The Zeeman Effect	218
6.3. Hyperfine Structure	228
6.4. The Line Width	236
6.5. The Zeeman Effect of the Green Line of ^{198}Hg	238
6.6. Saturation Absorption Spectroscopy of Rubidium	243
6.7. References	250
7 Magnetic Resonance Experiments	251
7.1. Introduction	251
7.2. The Rate for Magnetic-Dipole Transitions	255
7.3. Absorption of Energy by the Nuclear Moments	262

7.4. Experimental Observation of the Nuclear Magnetic Resonance of Protons	273
7.5. Electron Spin Resonance	283
7.6. References	293
8 Particle Detectors and Radioactive Decay	295
8.1. General Considerations	295
8.2. Interactions of Charged Particles and Photons with Matter	298
8.3. Gaseous Ionization Detectors; the Geiger Counter	320
8.4. The Scintillation Counter	333
8.5. Solid-State Detectors	344
8.6. Nuclear Half-Life Measurements	354
8.7. References	364
9 Scattering and Coincidence Experiments	367
9.1. Introduction	367
9.2. Compton Scattering	369
9.3. Mössbauer Effect	385
9.4. Detection of Cosmic Rays	399
9.5. γ - γ Angular Correlation Measurements	409
10 Elements from the Theory of Statistics	423
10.1. Definitions	423
10.2. Frequency Functions of One Variable	431
10.3. Estimation of Parameters and Fitting of Data	445
10.4. Errors and Their Propagation	454
10.5. The Statistics of Nuclear Counting	465
10.6. References	473
Appendices	
A Students	475
B A Short Guide to MATLAB	477
B.1. A MATLAB Review	478
B.2. Making Fancy Plots in MATLAB	481

C	<i>Laser Safety</i>	483
D	<i>Radioactivity and Radiation Safety</i>	485
E	<i>Optical Detection Techniques</i>	489
	E.1. Photographic Film	489
	E.2. Photomultiplier Tubes	490
	E.3. Photodiodes	496
F	<i>Constants</i>	499
G	<i>Exercises</i>	501
	Index	517