Physics 198

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# Introduction to Radiation Detectors and Electronics

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# *Preface*

The sequence of topics in this course is somewhat unorthodox. Rather than following a linear progression that first lays out all the fundamentals and then moves on to a descriptive compilation of detector types, I've attempted to first establish a systems perspective that explains the functional components of a detector system before moving on to a more detailed treatment. This includes some seemingly arcane details, as they frequently provide the critical ingredients that allow a detector to actually work. The grander goal of the course is to teach students how to recognize the key elements of any detector system and analyze their interactive roles, instead of approaching detector design as an agglomeration of pieces to be combined by empirical recipes.

This concept leads to a recursive approach where I first discuss two examples of detectors – scintillator-phototube systems and semiconductor detectors – to establish essential concepts and then in a second pass elaborate on semiconductor detectors to discuss the interplay of device physics, signal formation and electronic noise. The material is developed with a minimum of prerequisites and topics are introduced as needed. This leads to some unexpected detours, but in reality research hardly ever follows a direct path.

Chapters I through VII form the first part of the course, which covers the essentials of detectors, electronic noise, pulse shaping and signal digitization. These chapters by themselves provide sufficient background to use detectors, but not necessarily understand them. Chapter VIII covers a wide range of topics, including the calculation of induced signal charge, the physics of diodes and transistors and what determines the device characteristics relevant to detectors, an overview of device fabrication, and noise mechanisms in field effect and bipolar transistors. The chapter closes with a section on avalanche photodiodes, which normally would belong into the chapter on scintillation detectors, except that the physics background to understand them would be missing. Chapter IX shows how all these pieces are put together to develop a tracking system in a high-rate particle physics experiment and Chapter X discusses "Why Things Don't Work".

The course was directed toward upper division honors and graduate level physics students. As mentioned above, no special knowledge is required beyond a general knowledge of classical physics and basic quantum mechanics. Where needed, specialized results are derived in some detail to justify key results. This did take up more time than I originally planned, so I had to leave out a chapter on cryogenic detectors.

The course builds on numerous tutorial lectures I've given over the past two decades, primarily in IEEE sponsored short courses. Many thanks to my IEEE co-instructors, notably Glenn Knoll, Steve Derenzo and Eugene Haller, from whom I‘ve borrowed liberally.

In part this course was also an experiment. Whether it was successful, I don't yet know.
The notes are quite detailed and should provide a resource for self-study. Please let me know what is wrong and what should be improved.

Helmuth Spieler
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3. Bipolar Transistors
4. Field Effect Transistors
5. Noise in Transistors
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7. Photodiodes

IX. Development of a Tracker Concept

X. Why Things Don't Work