SYMMETRIES & CONSERVATIONS LAWS

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Contents

Messages

- **Conserved quantities** arise from **Symmetries.**
- **Group Theory** provides the language for understanding how **particles combine** and the structure of the **Standard Model**.
- We gain valuable insight, facilitating the **classification of particles** and the evaluation of their **interactions**

Introduction

Symmetries & Conservation Laws are found in **Classical Mechanics** – provides a taster of what follows in **Quantum Mechanics**.
Historically certain formulations of CM provide a framework for QM.
Symmetries are properties of systems under **Transformations**, and these can be obtained from **Generators**. The Generators are very useful for what follows.
In QM, Transformations can be associated with **Quantum Numbers**.

Groups are mathematical structures which are useful for describing sets of Transformations.
There are several key Groups which characterise the **Forces** of the **Standard Model**.
The most useful groups are associated with **Unitary Transformations**.
We will be less interested in the Groups and the Transformations themselves, but rather the Generators and **Representations** – the combinations of Quantum Numbers which are invariant under the Transformations. The Representations allow useful classifications of Forces and **Particles**.

The important groups for the Standard Model are:

- **U(1)** – **QED**, and also **Baryon Conservation**
- **SU(2)** – **Electroweak Symmetry**, and also **Spin**
- **SU(3)** – **QCD**, and also **Hadron States**

The Classification of Hadron States is mostly historical but can also provide some insight **Beyond the Standard Model**.

Acknowledgements

This course had its origins in earlier courses presented by **Paul Harrison** and **Alex Martin**.

References

"Lie Algebras in Particle Physics" – Howard Georgi – references to sections shown in [ ]

Also:
"Unitary Symmetry and Elementary Particles" – Lichtenberg – Group Theory and its applications
"Introduction to Quarks & Partons" – Close – Hadron Spectroscopy
"Quarks and Leptons" – Halzen & Martin – General
"Classical Mechanics" – Goldstein – Symmetries in Classical Systems

Health Warning

This course is quite difficult:

- Quantum Mechanics is intrinsically difficult: it is unnatural (to humans) and ultimately, like any theories, based on assumptions which *appear* to describe experimental observations.
- There is no perfect text book for what we want.
- There is a huge amount of background maths, and it is not appropriate or necessary for us to understand this.
- Consequently, our coverage will often seem superficial and many assertions will be unproven.

Homework

Homework will be given on separate sheet. Although “Homework” may be indicated in notes to show that there is something to prove, the proofs will be left for Homework.

There are 3 sheets – you should allow 2-3 hours for each.

“Exercises” are optional, for proofs which should be familiar from undergraduate courses or are straightforward … but I don’t want to write it out !

Exam

There will be an hour long **Exam Question** on this course in January.
It is often closely coupled to the Homework !

Help

If you have questions about the Lectures or the **Homework** (however trivial they may seem), do not hesitate to contact me at:

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