PHYS 8171 Quantum Theory of Scattering with Applications I
Fall 2017
Instructor: Phillip Stancil
TR 2:00pm-3:15pm, Physics 254
Prerequisite: PHYS 8102 or equivalent

Instructor Information

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Introduction

The goal of the course will be to give an introduction to collision theory. Collisions have played a crucial role in physics since the early days of the development of quantum theory. Scattering experiments have been used for the past century to delve into the structure of matter at all levels. Interpretation of such experiments and extraction of the microscopic particle interactions rests on the development of theoretical descriptions of scattering. Collisions also play important roles in a variety of applications from controlling the thermal balance in astrophysical gas to influencing the stability of dilute gas Bose condensates to plasma processing of material surfaces.

The flow of the course will follow the general outline given in Child's *Molecular Collision Theory*, but extensive additional material will be taken from Joachain's *Quantum Collision Theory* and other sources. The philosophy of the course approach will also be to follow Child's direction in "giving an essentially analytical treatment" of the subject while focusing on the quantum mechanical and semi-classical behavior of scattering. Therefore, the focus will be on time-independent approaches with the intent of giving the student useful tools for interpreting scattering measurements or to make simple predictions. However, as a foundation and to highlight quantal effects, some classical scattering will be presented and time-dependent and computational approaches will be introduced as appropriate.

I plan to spend roughly three-fourths of the course on the development of formal scattering theory with the remaining time on applications of current interest.

Preliminary Course Outline

- Descriptions of basic collision processes and observables
- Kinematics and coordinate systems

- Classical scattering by a central force
- General features of quantum scattering: elastic scattering
- Partial wave analysis
- Identical particles
- The Born series
- Semiclassicial approximations
- General theory of inelastic scattering
- Formal quantum scattering and scattering matrices
- Application: Coulomb potential scattering
- Application: numerical solutions for scattering
- Application: time-dependent wave packet methods
- Application: line broadening and line shifting
- Application: transport and diffusion processes, stopping powers
- Application: reactive scattering
- Application: ultracold collisions
- Application: Feshback resonances and magnetic-field tuning
- Application: non-adiabatic processes
- Application: collisions in astrophysics and atmospheric physics

Required Textbook

- *Molecular Collision Theory*, M. S. Child, Academic Press (1984) or Dover Publications (1996). Easy to find on Amazon, etc.

Additional Resources

- *Quantum Collision Theory*, C. J. Joachain, North-Holland Publishing (1975). Out of print.
- *The Theory of Atomic Collisions*, 3rd ed., N. F. Mott and H. S. W. Massey, Oxford Univ. Press (1965).
- *Scattering Theory of Waves and Particles*, R. G. Newton, McGraw-Hill (1966).
- *Collision Theory*, M. L. Goldberger and K. M. Watson, Wiley (1967).
- *Scattering Theory*, J. R. Taylor, Wiley (1972).
- *Theory and Application of Quantum Molecular Dynamics*, J. Z. H. Zhang, World Scientific (1999).

Assignments and Grading Policy

There will be four homework assignments given throughout the semester involving typical analytical problem solution. This will be supplemented with two programming projects. Further details about the programming projects will be given in class, but the intent is to create simple scripts (in any language) based on analytical formulae and analytical potentials to further develop understanding of scattering through graphical exploration of parameter space. Finally, a take-home final exam of a similar level and length as a homework set will be given in the last week of class. The student's final numerical score will be determined from the following weights from the assignments:

- 50% Average of homework assignments
- 30% Average of programming projects
- 20% Take-home exam score

The final letter grading scale determined from the composite of the course assignments will be: 100%-90% : A; 89.9%-85% : A-; 84.9%-77% : B+; 76.9%-70% : B; 69.9%-65% : B-; 64.5%-60% : C+; 59.9%-55% : C; 54.9%-50% : C-; 49.9%-45% : D; <45% : F.