Spring 2020 Rutgers University at Newark
Graduate Program in Physics

Physics 780: Advanced Quantum Mechanics

Course Information:
Time: Wednesday 6.00pm –8.50 pm
Place: SMT 240
Instructor: Neepa T. Maitra
Phone: 973-353-1573
Email: neepa.maitra@rutgers.edu (*best way to reach me)*
Office hour: Weds 4.00pm—5.30pm, or by appointment, Rm 357 Smith Hall

Pre-requisites:
Sufficient proficiency with non-relativistic quantum mechanics is required.

Recommended Reading:
Gabriele F. Giuliani and Giovanni Vignale, "Quantum Theory of the Electron Liquid", (Cambridge University Press, 2005)

E. K. U. Gross, E. Runge, and O. Heinonen, "Many-Particle Theory", Institute of Physics Publishing (1991) *(an electronic version will be made available to students in the class)*

John P. Perdew and Stefan Kurth: "Density Functionals for Non-Relativistic Coulomb Systems", in "A Primer in Density Functional Theory" Ed. C. Fiolhas, F. Nogueira, and M. Marques (Springer Lectures Notes in Physics, v.620, 2003). *(an electronic version will be made available to students in the class)*

E. K. U. Gross and N. T. Maitra: "Introduction to TDDFT", in *Fundamentals of Time-Dependent Density Functional Theory*, eds. M. A. L. Marques, N.T. Maitra, F. Nogueira, E. K. U. Gross, and A. Rubio (Springer-Verlag, Berlin-Heidelberg, 2012). *(an electronic version will be made available to students in the class)*

In addition to these, journal and review articles will be recommended as we go along.

Grading:
Homework: 70%
There will be about 5 long problem sets, due about every two weeks, including in-class demonstrations of problem-solving.
Seminar Presentation: 30%
During the last few weeks, you will prepare a half-hour seminar on a topic, chosen from a list. These topics will have arisen during class but not covered in depth; you will provide a focused lecture on one of them during your seminar. A preliminary list of topics will be available by the 4th week of class.

Course Syllabus (Tentative):

1. Identical Particles and Many-Body Interactions in Quantum Mechanics
(Introduction to interactions in many-body QM, N-electron wavefunctions, operators, reduced variables, density operators, review of second quantization, Hubbard model)

2. Jellium
(translationally invariant Hamiltonia, high versus low-density regimes, weak interaction limit, exchange energy, rs-expansion, Wigner crystal, (charge-density and spin-density waves))

3. The Hartree-Fock Approximation
(Hartree-Fock equations, ground-state and excitation energies, exchange energy and correlation energy, symmetry-dilemma, application to jellium)

4. Linear Response Theory
(general response functions, spectral representations, analytic properties, sum-rules, density-response, Lindhard function, dielectric function, random phase approximation, plasmons)

5. Many-Body Perturbation Theory
(Time-ordered correlation function, Green's function and self-energy, screened interactions, Bethe-Salpeter equation, Hedin's equations, GW approximation)

6. Density Functional Theory
(Hohenberg-Kohn theorem, Kohn-Sham equations, exchange-correlation energy, exact properties of functionals, approximate functionals)

7. Time-Dependent Density Functional Theory
(Runge-Gross theorem, time-dependent Kohn-Sham, excitation energies, electron-energy-loss spectra, optical spectra of solids, adiabatic approximation, exact properties)

(8. Phonons – if time allows)
(Born-Oppenheimer approximation, lattice vibrations, acoustic and optical phonons)