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)

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,
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)