NPRE-521: Interaction of Radiation with Matter

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Schedule: Lectures: Tuesday and Thursday, 14:00 – 16:00, 100H Talbot Laboratory
Recitation: Monday, 14:00 – 15:00, 100H Talbot Laboratory
Office Hours: Upon request or stop by

Course Website: http://zhang.npre.illinois.edu/teaching.html

Credit: 4 graduate hours

Prerequisite: NPRE 446/447 or equivalent

Grading: 1) Homework (40%). Late homework is accepted, but 10% of the score will be deducted per day until 50% is reached.
2) Mid-term exam (30%), Final exam (30%). A letter size hand-written only cheat sheet (otherwise half of the score will be deducted) is allowed during the exam. The cheat sheet will be collected at the end of the exam, but will not graded.

Description: The classical and quantum theories of the interaction of radiation (heavy and light charged particles, electromagnetic waves, photons, and neutrons) with matter are the core components of nuclear science and engineering. This course is the Part I of the sequence of two graduate-level courses on the subject. It provides quantitative treatments of single interaction event. The Part II, NPRE-529 Interaction of Radiation with Matter II: Multiple Events and Computational Methods, extends the material to multiple events and collective phenomena, which are common in real systems.

Topical Outline:

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<th>Topic</th>
<th>Contact Hours</th>
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<td>0. Overview</td>
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<td>1. Classical Interaction</td>
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<td>Newton’s formalism, Principle of virtual work, Principle of least action, Euler-Lagrange equation (Lagrange multiplier), Rutherford scattering, Legendre transformation, Hamilton’s equations, conservation laws and symmetry, canonical transformation, symplectic condition, canonical invariants, Poisson bracket, Liouville’s theorem, Hamilton-Jacobi equation</td>
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<td>2. Classical Electromagnetic Interaction</td>
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<td>Maxwell equations, Lorentz force density, energy and momentum of electromagnetic fields (Poynting vector, Maxwell stress tensor), boundary conditions, electrostatics (Laplace equation, Poisson equation, uniqueness theorem, method of images, separation of variables, multipole expansion), magnetostatics, electromagnetic waves (propagation, reflection, refraction, polarization, in conductor, wave guide), electromagnetic radiation (gauge transformation, retarded potential, Lienard–Wiechert potential, Jefimenko’s equations, dipole radiation, Larmor formula, bremsstrahlung/synchrotron/Cherenkov radiation, Abraham–Lorentz force), electromagnetic wave scattering (Rayleigh scattering), special relativity</td>
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<td>3. Non-relativistic Quantum Mechanics and Atomic Structure</td>
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<td>Limitations of classical theory (photoelectric effect, Compton scattering), wave-particle duality, Schrödinger equation, conservation of probability density, bound/unbound states, ladder operator, formalism (Hilbert space, Bra-ket notation), matrix representation, uncertainty principle, atomic orbitals, identical particles, perturbation method, Bohn</td>
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approximation, Fermi’s golden rules, double differential scattering cross section

4. Review and Outlook 2
Exams 2
Total 58

Recommended Texts:

**Essential Physics (Basic Level):**


**Essential Physics (Advanced Level):**


**Nuclear Physics:**