Fall 2009 GWPI Physics Graduate Courses

Last Revision: September 10, 2009

Note: All classes are in the Main Link Room (EIT2053 at UW or MACN 101 at UofG) and classes commence the week of September 14, 2009 unless otherwise stated

701 (UW) 7010 (UofG) Quantum Mechanics I
Instructor: Kevin Resch Time: MW 4:00-5:30
Review of formalism of nonrelativistic quantum mechanics including symmetries and invariance. Approximation methods and scattering theory. Elementary quantum theory of radiation. Introduction to one-particle relativistic wave equations.
Recommended Text: *Principles of Quantum Mechanics 2nd edition*, R. Shakar (published by Springer, ISBN 0-306-44790-8)

704 (UW) 7040 (UofG) Statistical Physics I
Instructor: Robert Wickham Time: TTh 1:00-2:30
Statistical basis of thermodynamics; ensemble theory; quantum statistical mechanics; fluctuations, correlations and response; application to gases, liquids, solids; phase transitions
Suggested Texts:
R. K. Pathria, *Statistical Mechanics*
H. B. Callen, *Thermodynamics and an Introduction to Thermostatistics*
J. P. Sethna, *Statistical Mechanics: Entropy, Order Parameters and Complexity*
D. Chandler, *Introduction to Modern Statistical Mechanics*
G. Mazenko, *Equilibrium Statistical Mechanics*
M. Kardar, *Statistical Physics of Particles*
M. Plischke and B. Bergersen, *Equilibrium Statistical Mechanics*
D. L. Goodstein, *States of Matter*

712-1 (UW) Selected Topics in Theoretical Physics Topic: String Theory 2.0: Introduction to AdS/CFT Correspondence Instructor: Robert Myers Time: TBA Location: TBA (PI)
NOTE: Instructor consent required; contact the instructor (rmyers@perimeterinstitute.ca) if you are interested in taking this course.

UW students will require a permission number to enroll in this course. Contact gwp@sciborg.uwaterloo.ca in order to obtain this number.

This will be a course for graduate students interested in learning about the AdS/CFT correspondence or gauge/gravity duality. This is one of the central tools in modern superstring theory. In this course, we will be making select readings from various sources, including:

J.M. Maldacena, *Lectures on AdS/CFT*, arXiv:hep-th/0309246;

E. D'Hoker and D.Z. Freedman, *Supersymmetric gauge theories and the AdS/CFT correspondence*, arXiv:hep-th/0201253;

O. Aharony, S.S. Gubser, J.M. Maldacena, H. Ooguri and Y. Oz, *Large N field theories, string theory and gravity,* Physics Reports **323**, 183 (2000) [arXiv:hep-th/9905111].

The topics covered include: D3-branes (at weak and strong coupling); N=4 super-Yang-Mills theory; large-N counting; conformal invariance in field theory; geometry of anti-de Sitter space; field/operator dictionary; computation to correlators; Wilson loops; modeling confinement; black hole mechanics; AdS black holes and thermal gauge theory.

The course evaluation will be based on regular problem sets that will be handed in during the term. I will also ask the students to give presentations on various course topics to the class. The presentation and the sum of the problem sets will be weighted as 20% and 80%, respectively, in formulating the final grade.

Students will be admitted to the course by permission of the instructor. Prerequisites for the course include having taken introductory courses in general relativity and quantum field theory. An introduction to string theory is also recommended but not essential.

7120-01 (UofG) Selected Topics in Theoretical Physics Topic: Introduction to General Relativity <u>Instructor:</u> Eric Poisson <u>Time:</u> TBA <u>Location:</u> TBA (UofG) <u>NOTE:</u> Instructor consent required; contact the instructor (poisson@physics.uoguelph.ca**) if you are interested in taking this course.**

UofG students will need to complete a 'Course Add/Drop & Change' (found at: http://www.uoguelph.ca/registrar/graduatestudies/files/addform.pdf) form in order to enroll in this course.

Classes will meet once a week in a designated room (TBD). Students will be responsible for learning the material from the textbook and additional references. Each week one or two students (in turn) will be asked to give a presentation on what they have learned, for the benefit of the other students. Classes will be organized around these presentations, with the instructor frequently stepping in to clarify and expand the discussion.

<u>Required Textbook</u> The recommend textbook for the course is *A first course in general relativity (Second Edition)* by Bernard F. Schutz (Cambridge University Press; ISBN-10: 0521887054; ISBN-13: 978-0521887052). Each student is responsible for the purchase of his/her copy.

<u>Additional references</u>

S.M. Carroll, *Spacetime and geometry: An introduction to general relativity* (Addison Wesley, San Francisco, 2004; QC 173.6.C377).

J.B. Hartle, Gravity: *An introduction to Einstein's general relativity* (Addison Wesley, San Francisco, 2003; QC 173.6.H38).

R. d'Inverno, *Introducing Einstein's relativity* (Clarendon Press, Oxford, 1992; QC 173.55.D56).

C.W. Misner, K.S. Thorne, and J.A. Wheeler, *Gravitation* (Freeman, New York, 1973; QC 178.M57).

R.M. Wald, *General relativity* (University of Chicago Press, Chicago, 1984; QC

173.6.W35).
S. Weinberg, *Gravitation and cosmology* (Wiley, New York, 1972; QC 6.W47).
Evaluation: Grades will be based on the presentations (20%), homework assignments (40%), and a final take-home exam (40%). Homework problems will be given out every second or third week.

733 (UW) 7330 (UofG) Special Topics in Theoretical Condensed Matter Physics: Superconductivity
Instructor: Elisabeth Nicol Time: MW 9:00-10:30
NOTES:
Classes will run until December 7th, 2009.
Instructor consent required; contact the instructor (nicol@physics.uoguelph.ca) if you are interested in taking this course.

(1) UW students will require a permission number to enroll in this course. Contact gwp@sciborg.uwaterloo.ca in order to obtain this number.
(2) UofG students will need to complete a 'Course Add/Drop & Change' (found at: http://www.uoguelph.ca/registrar/graduatestudies/files/addform.pdf) form in order to enroll in this course.

This course has been designed for both experimental and theoretical graduate students and therefore has an emphasis on both experiment and theory.The course will begin with a review of the properties exhibited by superconductors including conventional, organics, alkali-doped C_{60}, heavy fermions, the high Tc copper oxides and the new iron superconductors. The properties considered will include among others: specific heat, thermodynamics, critical fields, optical properties, penetration depth, magnetization, transport, thermal conductivity, ultrasonic attenuation, etc. Evidence will be given from experiment for electron pairing in a spin singlet state and flux quantization with charge 2e. I will then give a detailed discussion of Cooper pair formation and the idea of an energy gap, and a long coherence length leading to the BCS wave function and the macroscopic condensation of Cooper pairs into a condensate. The microscopic theory of the superconducting statein BCS theory is developed using 2nd quantization notation (which is very intuitive)rather than many body finite temperature Green's functions.This will lead to special properties such as a jump in the specific heat at Tc and an exponential temperature-dependent specific heat at low temperature, etc. The issue of the symmetry of the order parameter or the gap will also be considered and stressed as this is an important issue for newer superconductors. Depending on time and interest other topics may be discussed such as, the Josephson effect, the Bogoliubov-de Gennes equations, or specific topics of interest to the students in the class.
Text:
Copies of the lecture notes will be handed out, but in addition, one might wish to refer to some of the classic texts:

P.G. DeGennes, *Superconductivity of Metals and Alloys*, W.A.Benjamin, New York, 1966. (Much material on Type II superconductors and the Abrikosov lattice.)

J.R. Schrieffer, *Theory of Superconductivity*, W.A. Benjamin, New York, 1964 (Microscopic theory using Green's functions.)
G. Rickayzen, *Theory of Superconductivity*, John Wiley and Sons, New York, 1965. (Microscopic theory without Green's functions.)
M. Tinkham, *Superconductivity*, Gordon and Breach, New York, 1965. Note that there is a second edition now available. (A simpler approach to microscopic theory.)

746 (UW) 7460 (UofG) Nonlinear Optics
Instructor: Donna Strickland Time: MW 1:00-2:30 in the Main Link Room
Classical and quantum mechanical descriptions of nonlinear susceptibility; nonlinear wave propagation; nonlinear effects such as Pockel's and Kerr effects, harmonic generation, phase conjugation and stimulated scattering processes.
Required Text: *Nonlinear Optics*, 2^{nd} ed. By R.W. Boyd ISBN#0121216829

751 (UW) 7510 (UofG) Cellular Biophysics (cross listed with Phys 4560 at UofG)
Instructor: John Dutcher Time: TTh 11:30-1:00
This course introduces students to a wide variety of physical techniques used in modern biophysics research. The molecular biophysics of cellular membranes will be discussed in detail, including the structure and function of major membrane components, lipids, proteins and carbohydrates. The course also aims to improve the oral and written communication skills of the students. The course work assumes knowledge of quantum mechanics and statistical mechanics at an introductory level. It is also very useful if the students have had an exposure to molecular biology and biochemistry.
References:
The students will be provided with an electronic collection of important reviews on the techniques of interest (licensed to University of Guelph). The students are also encouraged to read major biophysical and biochemical journals (links are provided on the course website: **http://www.physics.uoguelph.ca/~dutcher/phys4560/**.)

767 (UW) 7670 (UofG) Introduction to Quantum Information Processing
Instructor: Richard Cleve Time: TTh 2:30- 4:00
Location: MC2036B (UW)
Review of basics of quantum information and computational complexity; Simple quantum algorithms; Quantum Fourier transform and Shor factoring algorithm; Amplitude amplification, Grover search algorithm and its optimality; Completely positive trace-preserving maps and Kraus representation; Non-locality and communication complexity; Physical realizations of quantum computation: requirements and examples; Quantum error-correction including CSS codes, and elements of fault-tolerant computation; Quantum cryptography; Security proofs of quantum key distribution protocols; Quantum proof systems.
(Main) Recommended Text: *An Introduction to Quantum Computing*, by P. Kaye, R. Laflamme, M. Mosca ISBN#978-0-19-857049-3 (Oxford University Press)
Recommended Text: *Quantum Computation and Quantum Information*, by M.A. Nielsen and I. L. Chuang, ISBN#0-521-63503-9 (Cambridge University Press)

7710-02 (UofG) Special Lecture and Reading Course Topic: Practical X-Ray Spectrometry <u>Instructor:</u> Iain Campbell <u>Time:</u> MT 9-10:30 <u>Location:</u> MACN 434 (UofG) <u>NOTE:</u> Instructor consent required; contact the instructor (jlc@physics.uoguelph.ca) if you are interested in taking this course.

UofG students will need to complete a 'Course Add/Drop & Change' (found at: http://www.uoguelph.ca/registrar/graduatestudies/files/addform.pdf) form in order to enroll in this course.

<u>Objective</u>

To impart a basic knowledge of the underlying physics and the practice of X-ray spectrometry as a means of elemental analysis

<u>Syllabus</u>

- Interactions of photons, electrons and light ions with matter; mechanisms of atomic inner-shell vacancy creation; cross-sections for ionizing processes.
- Physics of inner-shell vacancy de-excitation; level widths, linewidths, X-ray and auger electron emission, fluorescence and Coster-Kronig probabilities, diagram line relative intensities, satellites.
- Bragg spectroscopy.
- Energy-dispersive spectroscopy with SDD, Si(Li) and Ge detectors; spectrum features; detector response functions and efficiency; escape and pile-up peaks, digital versus analog signal processing; spectrum fitting.
- Elemental analysis by XRF, EPMA and PIXE; matrix effects; quantitation.

<u>Reference texts</u>

Van Grieken and Markowicz, Handbook of X-ray Spectrometry, Dekker, 1993.
Johansson, Campbell, Malmqvist, Particle-induced X-ray Emission, Wiley, 1995.
Zschornack. Handbook of X-ray Data, Springer, 2007.
Extensive use will be made of research articles in the refereed literature

<u>Evaluation</u>

This will be accomplished by assigning large term projects. Each student will research a specific course topic in depth and will present two lectures and a printed report on her/his topic.

773-1 (UW) Special Topics in Physics: Nanoelectronics for Quantum Computing <u>Instructors:</u> Frank Wilhelm-Mauch and Adrian Lupascu <u>Time:</u> WF 2:30-3:50 <u>Location:</u> RAC 3004 (UW) <u>NOTE:</u> Instructor consent required; contact the instructors (fwilhelm@iqc.ca or alupascu@iqc.ca) if you are interested in taking this course

UW students will require a permission number to enroll in this course. Contact gwp@sciborg.uwaterloo.ca in order to obtain this number.

This course is going to introduce the physical foundations of quantum computing with nanodevices, mostly with superconducting circuits. It is aimed at graduate students pursuing research in this and/or related areas.Topics include:

Superconductivity (Sept 16-25)
Josephson Effect (Sept 30-Oct 2)
Quantization of Electrical Circuits; Phase, Charge, and Flux Qubits (Oct 7-16)

Decoherence (Oct 21-30)
Circuit QED (Nov 4-6)
Superconducting Detectors: Flux and Charge Detectors (Nov 11-13)
Quantum Measurements of Superconducting Qubits and Resonators (Nov 18-20)
Experimental Methods for Superconducting Qubit Experiments: Microfabrication and Low Temperatures (Nov 25-27)
Experimental Methods for Superconducting Qubit Experiments: Microwave Generation, Pulse Shaping, Low-Noise Measurements (tentative Dec 2-4)

Course Evaluation will be based on homework assignments (5 @ 10% each) and a final project worth 50% to be presented December 16th.
Textbook/Resource Information: TBA

781 (UW) 7810 (UofG) Fundamentals of Astrophysics
Instructor: James Taylor Time: TTh 10:00-11:30
This course is designed to provide a basic theoretical background for students in Astronomy, Astrophysics, or related areas. We will spend roughly a third of the course on each of radiative processes (ibasically E&M in an astrophysical context), gravitational dynamics, and fluid dynamics/plasma physics.
Specific topic include: Overview of astronomical observations. Radiative processes: macroscopic description, thermal & non-thermal emission, scattering, line transitions & plasma effects. Gravitational dynamics: potentials & orbits, self-gravitating systems, the collisionless Boltzmann equation, gravitational encounters. Fluid Mechanics: simple fluids, sound waves & shocks, instabilities and transport mechanisms.

Recommended Texts: *Galactic Dynamics* by Binney & Tremaine ISBN#9780691130279 (Princeton University Press) *The Physics of Fluids and Plasmas An Introduction to Astrophysics* by Arnab Rai Choudhuri, ISBN#052155543 (Cambridge University Press) *Radiative Processes in Astrophysics* by George B. Rybicki and Alan P. Lightman, ISBN#0471048151(1986) (John Wiley & Sons Inc.)

A single, general reference covering all of this material in more detail is: T. Padmanabhan, *Theoretical Astrophysics, Volume I: Astrophysical Processes*

786 (UW) 7860 (UofG) General Relativity for Cosmology
(cross listed with AMath 875 at UW)
Room: Rozanski 106 at UofG and Bob Room 405 at Perimeter Institute and MC6091 at UW
Instructor: Achim Kempf Time: Monday & Thursday 4:00-5:30
NOTE: Course starts September 21st.

Differential geometry of Lorentzian manifolds, including vielbein formalism and spinors. The principles of general relativity, also in terms of forms and as a gauge theory. Causal structure and cosmological space-times. Scalar, vector and tensor perturbations and inflationary cosmology. Preparations for quantum gravity.
Required Texts: Instructor will provide lecture notes electronically.

788-1 (UW) Selected Topics in Astronomy: Introduction to Observational Astronomy **<u>Instructor:</u> David Gilbank (UW contact Michael Balogh)**
<u>Time:</u> MF 10:30-11:50 <u>Room:</u> PAS 2084 (UW)
<u>NOTE:</u> Instructor consent required; contact the instructors (dgilbank@astro.uwaterloo.ca) if you are interested in taking this course.

UW students will require a permission number to enroll in this course. Contact <u>gwp@sciborg.uwaterloo.ca</u> in order to obtain this number.

This course will present methods useful for research in observational astronomy, covering everything from planning observations to taking data, reducing it and common statistical techniques. The emphasis will be on data reduction and analysis methods relating to optical and near-infrared data in extra-galactic astronomy, but with a broad enough overview to show how the techniques are applicable to other fields.

The course will assume students have no background in astronomy, and the introductory material will review the relevant physics and basic statistics. The bulk of the course will relate to CCD (and similar) detectors, their operation and use, object detection, photometry, astrometry and spectroscopy. There will also be a practical statistics component covering topics such as small number statistics, hypothesis testing, maximum likelihood, etc.

Assessment will be approximately 50% based on practical data reduction exercises (both in class and take-home); 20% problem sheets; and 30% a small project based on a practical problem in observational astronomy.

There is no required textbook and most of the material will be based on research papers which are available online. Two textbooks which may be useful are (both from the Cambridge Observing Handbooks for Research Astronomers series):
- Handbook of CCD astronomy by Steve B. Howell
- Practical statistics for astronomers by J. V. Wall and C. R. Jenkins.