**PHYS 8803: Computational Physics**

Fall 2011, MWF 1:05pm-1:55pm, Howey Bldg N210

**Instructor:** Prof. Pablo Laguna

**Office:** 1-63 Boggs Building

**Email:** [plaguna@gatech.edu](mailto:plaguna@gatech.edu)

**Office hours:** 2:00pm-3:00pm MWF or by appointment

**Class website:** http://laguna.gatech.edu/CompPhys/index.html

**Suggested Textbooks:**

|  |  |  |
| --- | --- | --- |
|  |  | 1. A First Course in Computational Physics, 2nd Edition, Paul L. DeVries and Javier E. Hasbun (Jones and Barlett, 2011) 2. Numerical Recipes, 3th Edition, by William H. Press, Saul A. Teukolsky, William T. Vetterling and Brian P. Flannery (Cambridge University Press 2007) |

**Course Objectives:** Applications of numerical methods and computer programming to condensed matter; astrophysical hydrodynamics, gravitational physics, black holes and cosmology.

**Course grades:**

**HOMEWORK:** There will be THREE homework assignments during the semester. Homework problems will typically require writing computer programs based on the numerical algorithms discussed in class. Computer programs MUST be written completely from scratch, with the essential steps fully commented. The structure of the program can, however, be based, if necessary, on programs written or discussed by the instructor. The instructor reserves the right to request the student the reproduction of results submitted in homework assignments. Delays in the submission of homework sets will be penalized 2 points per day.  
  
**TEAM PROJECT:** 2/5 of the course grade is assigned from a project. The project consists of two parts. One of them is an oral presentation the week before dead week. The second part is a written report, between 3 and 5 pages in length, due the day of the final exam. The teams for the projects could have a minimum of 3 and maximum of 5 members.  The research project should clearly require the use of numerical methods. All members of each team participate in the oral presentation. At the end of each presentation there will be a Q&A session involving fellow classmates and the instructor.  Both, the final report and oral presentation must include:  
1) description of the nature of the problem,   
2) the numerical techniques used,   
3) code testing,  
4) results, using scientific visualization where applicable, and   
5) scientific implications.

**GRADES**: The homework assignments are computed on a 0-100 point scale. Their weights are:

|  |  |  |
| --- | --- | --- |
| Homework 1 ([PDF](http://laguna.gatech.edu/CompPhys/Homework/hw1.pdf)) | 20 % | Due February 10, 2012 |
| Homework 2 ([PDF](http://laguna.gatech.edu/CompPhys/Homework/hw2.pdf)) | 20 % | Due March 16, 2012 |
| Homework 3 ([PDF](http://laguna.gatech.edu/CompPhys/Homework/hw3.pdf))  [magnetic.m](http://laguna.gatech.edu/CompPhys/Homework/magnetic.m) [magnetic\_plot.m](http://laguna.gatech.edu/CompPhys/Homework/magnetic_plot.m) | 20 % | Due April 18, 2012 |
| Project Presentation | 20 % | Due |
| Project Report | 20 % | Due |
| Total | 100 % |  |

The final letter grade is assigned using the following conversion table.

|  |  |
| --- | --- |
| A | 100 - 85 |
| B | 84 - 75 |
| C | 74 - 65 |
| D | 64 - 55 |
| F | 55 - 0 |

**Topics**

[Introduction](http://laguna.gatech.edu/CompPhys/Lectures/Introduction.pdf)  
  
[Solving Non-linear equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_01.pdf)

* Bisection method
* Linear interpolation
* Newton-Raphson Method
* Programs: [findroot.m](http://laguna.gatech.edu/CompPhys/Programs/findroot.m) [froot.m](http://laguna.gatech.edu/CompPhys/Programs/froot.m) [dfroot.m](http://laguna.gatech.edu/CompPhys/Programs/dfroot.m) [d2froot.m](http://laguna.gatech.edu/CompPhys/Programs/d2froot.m)

[Solving systems of equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_02.pdf)

* Gaussian elimination
* Iterative methods
* Matrix inversion
* Eigenvalues and Eigenvectors
* Non-linear systems

[Interpolation and curve fitting](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_03.pdf)

* Polynomials
* Cubic Splines
* Least Squares Fitting

[Numerical Integration](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_04.pdf)

* Trapezoidal rule
* Simpson rule
* Romberg integration
* Splines and Integration

[Numerical Approximations to Derivatives](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_05.pdf)

* Finite Differences
* Truncation Errors & Convergence
* Richardson Extrapolation
* Programs: [deriv.m](http://laguna.gatech.edu/CompPhys/Programs/deriv.m)

[Ordinary Differential Equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_06.pdf)  
Initial-value Problems

* Euler Method: [ode\_euler.m](http://laguna.gatech.edu/CompPhys/Programs/ode_euler.m)
* Runge-Kutta Methods
* Stellar Models: [stellar.m](http://laguna.gatech.edu/CompPhys/Programs/stellar.m), [stellar\_rhs.m](http://laguna.gatech.edu/CompPhys/Programs/stellar_rhs.m), [chandra.m](http://laguna.gatech.edu/CompPhys/Programs/chandra.m)

[Ordinary Differential Equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_07.pdf)  
Boundary-value Problems

* Tri-diagonal Solver
* Shooting method: [shooting.m](http://laguna.gatech.edu/CompPhys/Programs/shooting.m), [shooting\_rhs.m](http://laguna.gatech.edu/CompPhys/Programs/shooting_rhs.m)

[Partial Differential Equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_08.pdf)

* PDEs examples
* Advection Equation: [advect.m](http://laguna.gatech.edu/CompPhys/Programs/advect.m), [advect\_rhs.m](http://laguna.gatech.edu/CompPhys/Programs/advect_rhs.m), [euler.m](http://laguna.gatech.edu/CompPhys/Programs/euler.m), [rk2.m](http://laguna.gatech.edu/CompPhys/Programs/rk2.m), [rk4.m](http://laguna.gatech.edu/CompPhys/Programs/rk4.m)
* von Neumann Stability Method
* Method of Lines
* Burgers Equation: [burgers.m](http://laguna.gatech.edu/CompPhys/Programs/burgers.m), [burgers\_rhs.m](http://laguna.gatech.edu/CompPhys/Programs/burgers_rhs.m)

[Time-dependent Partial Differential Equations](http://laguna.gatech.edu/CompPhys/Lectures/Inflation.pdf)

* Hyperbolic Equations
* Cosmological Inflation
* Domain Walls: [inflation.m](http://laguna.gatech.edu/CompPhys/Programs/inflation.m)

[Time-dependent Partial Differential Equations](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_09.pdf)

* Diffusion Equations
* Proto-planetary disks

[Schrodinger Equation](http://laguna.gatech.edu/CompPhys/Lectures/Chapter_10.pdf)

* Time dependent using Crank Nicholson
* Time dependent using Iterative Crank Nicholson
* Stationary Solutions

Time-independent Partial Differential Equations

* Successive Over-relaxation
* Poisson Equation

Monte Carlo Methods

* Simple Monte Carlo integration
* Von Neumann Rejection Method
* Maxwell-Boltzmann distribution
* 2D Ising Model

Fourier Analysis

* Fast Fourier Transform
* Convolution and Correlation

**Statement of Intent for Inclusivity**

As a member of the Georgia Tech community, I am committed to creating a learning environment in which all of my students feel safe and included. Because we are individuals with varying needs, I am reliant on your feedback to achieve this goal. To that end, I invite you to enter into dialogue with me about the things I can stop, start, and continue doing to make my classroom an environment in which every student feels valued and can engage actively in our learning community.

**Attendance:** Each student should be aware of the regulations that are listed in the student handbook. The class attendance policy, which the Georgia Tech regulations say shall be at the discretion of the instructor, will be as follows: There will be no prescribed maximum number of unexcused absences for this class. However, if it is apparent that lack of attendance at class may be impairing a student's performance in the course, the instructor may require that the student not miss more classes, under the penalty of failing the course. Please consult <http://catalog.gatech.edu/rules/4/> for details on what constitutes an excused absence and other aspects of the Georgia Tech Attendance Policy.

**Academic Integrity:** Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit either of these links ([one](http://www.google.com/url?q=http%3A%2F%2Fwww.catalog.gatech.edu%2Fpolicies%2Fhonor-code%2F&sa=D&sntz=1&usg=AFQjCNGSnI7XUtRb62Pt5F8MFpZn-L-pDg), [two](http://www.google.com/url?q=http%3A%2F%2Fwww.catalog.gatech.edu%2Frules%2F18%2F&sa=D&sntz=1&usg=AFQjCNFks6LlbOi1HrzuLsGncccLPIzVDA)). Any student suspected of cheating or plagiarizing on an assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

**Accommodations for Individuals with Disabilities:** If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or [this link](http://www.google.com/url?q=http%3A%2F%2Fdisabilityservices.gatech.edu%2F&sa=D&sntz=1&usg=AFQjCNFRnBbHdUUMo9Kp24mJRGrjE9YZTw), as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

**Student-Faculty Expectations:** At Georgia Tech we believe that it is important to continually strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See [this link](http://www.google.com/url?q=http%3A%2F%2Fwww.catalog.gatech.edu%2Frules%2F22%2F&sa=D&sntz=1&usg=AFQjCNGmR4gHww27Af_yPg0W0ER7RkVqyQ) for an articulation of some basic expectations – that you can have of me, and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech, while in this class.

**Unexpected Problems:** If a snow and/or ice storm (or any other cause for the Institute to close) occurs on a day scheduled for a problem set due date, it will be due on the first day the Institute opens again. Submit your assignment to the previously specified venue (for example, T-square or email) if class is not held that day. Check the GT web pages and class announcements on T-square for information.

**Support Services and Resources**

In your time at Georgia Tech, you may find yourself in need of support. Below you will find some resources to support you both as a student and as a person.

***Academic support***

* Center for Academic Success [http://success.gatech.edu](http://success.gatech.edu/)
  + 1-to-1 tutoring <http://success.gatech.edu/1-1-tutoring>
  + Peer-Led Undergraduate Study (PLUS) <http://success.gatech.edu/tutoring/plus>
  + Academic coaching http://success.gatech.edu/coaching
* Residence Life's Learning Assistance Program <https://housing.gatech.edu/learning-assistance-program>
  + Drop-in tutoring for many 1000 level courses
* OMED: Educational Services (<http://omed.gatech.edu/programs/academic-support>)
  + Group study sessions and tutoring programs
* Communication Center ([http://www.communicationcenter.gatech.edu](http://www.communicationcenter.gatech.edu/))
  + Individualized help with writing and multimedia projects

***Personal Support***

Georgia Tech Resources

* The Office of the Dean of Students: <http://studentlife.gatech.edu/content/services>; **404-894-6367**; Smithgall Student Services Building 2nd floor
  + You also may request assistance at <https://gatech-advocate.symplicity.com/care_report/index.php/pid383662?>
* Counseling Center: [http://counseling.gatech.edu](http://counseling.gatech.edu/); **404-894-2575**; Smithgall Student Services Building 2nd floor
  + Services include short-term individual counseling, group counseling, couples counseling, testing and assessment, referral services, and crisis intervention. Their website also includes links to state and national resources.
  + *Students in crisis may walk in during business hours (8am-5pm, Monday through Friday) or contact the counselor on call after hours at* ***404-894-2204****.*
* Students’ Temporary Assistance and Resources (STAR): <http://studentlife.gatech.edu/content/need-help>
  + Can assist with interview clothing, food, and housing needs.
* Stamps Health Services: [https://health.gatech.edu](https://health.gatech.edu/); **404-894-1420**
  + Primary care, pharmacy, women’s health, psychiatry, immunization and allergy, health promotion, and nutrition
* OMED: Educational Services: [http://www.omed.gatech.edu](http://www.omed.gatech.edu/)
* **Women’s Resource Center:** [**http://www.womenscenter.gatech.edu**](http://www.womenscenter.gatech.edu/)**; 404-385-0230**
* **LGBTQIA Resource Center:** [**http://lgbtqia.gatech.edu/**](http://lgbtqia.gatech.edu/)**; 404-385-2679**
* **Veteran’s Resource Center:** [**http://veterans.gatech.edu/**](http://veterans.gatech.edu/)**; 404-385-2067**
* **Georgia Tech Police: 404-894-2500**