POSTER EJ01-19: COMPUTATION IN THE LAWRENCE PHYSICS CURRICULUM

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Fundamental Convictions

In approaching problems in physics, physicists

- Solve algebraic equations
- Solve ordinary differential equations
- Solve partial differential equations
- Evaluate integrals
- Find roots, eigenvalues, and eigenvectors
- Acquire and analyze data
- Graph functions and data
- Fit curves to data
- Manipulate Images
- Prepare reports and papers

Physicists of the 21-st century must be able to use computational approaches alongside analytic approaches, and hence must be familiar with

- An operating system, preferably UNIX or LINUX
- A text editor, e.g., nedit
- A spreadsheet, e.g. EXCEL
- An array processor, e.g., IDL, MATLAB
- A symbolic manipulator, e.g. MAPLE, MATHEMATICA
- A visualization tool
- A computational language, e.g., FORTRAN, C, C++
- A technical publishing system, e.g. LaTeX
- A presentation program, e.g., PowerPoint
- A program for data acquisition, e.g., LabView

To prepare majors, our curricula must

- Introduce computational resources *early*
- Use computational resources *throughout the curriculum*
- Focus *initially* on the tools themselves
- Warn of the hazards of finite-precision arithmetic

Infrastructure

Introductory Physics Laboratory

Hardware: 8 HP PCs, LabPro interfaces and several sensors;
Software: EXCEL, Kaleidagraph, LoggerPro, Microsim 7, Praat

Computational Physics Laboratory

Hardware: 10 HP xw9300 Linux workstations, HP ProliantDL380 file server, HP 4200DTN monochrome printer, Tektronix Phaser 350 color printer
Software: IDL, MAPLE, C and FORTRAN compilers, text editors, LaTeX, ODEPACK, MUDPACK, MARC/MENTAT, Numerical Recipes Library

Advanced Physics Laboratory

Hardware: 5 PCs with interface cards, measuring instruments with computer compatibility
Software: LabView; assorted drivers

The Lawrence Response

- Equip introductory and advanced laboratories and build the Computational Physics Laboratory (CPL), to which majors have 24/7 access; see panel at bottom of first column
- Introduce computer acquisition and analysis of data in the introductory laboratories
- Introduce *Computational Mechanics*, a required sophomore course that orients majors to the CPL; see panel in third column
- Introduce *Computational Physics*, an elective junior/senior course that focuses on PDEs; see panel in fourth column
- Include computer acquisition and analysis of data in *Advanced Laboratory*
- Incorporate computer-based exercises in other courses
- Expect students to use computer-based approaches on their own initiative in other contexts

Typical Physics Program

Bold and **Bold** = explicit use of computers
Red + **Red** = required for minimum physics major

	Term 1	Term 2	Term 3
Fresh	Elective Calculus I Freshman Studies	**Intro Class Physics** Calculus II Freshman Studies	**Intro Modern Physics** Calculus III Elective
Soph	**Electronics** Linear Alg/ODE Elective	**Comput Mech** Elective Elective	**Electromag Theory** Elective Elective
Junior	**Quantum Mech** Language Elective	**Advanced Lab** Language Elective	Physics Elective Language Elective
Senior	Capstone Project Elective Elective	Physics Elective Elective Elective	Physics Elective Elective Elective

Available Physics Electives:

- Thermal Physics
- Optics
- Solid State Physics
- Advanced Modern Physics
- Laser Physics
- **Advanced E and M**
- **Mathematical Methods**
- **Advanced Mechanics**
- **Computational Physics**
- **Plasma Physics**
- Special Topics (Relativity, Fluids, Particle Physics
- Tutorial
- Independent Study

Curricular Components

Freshman Year:

- Data acquisition (LabPro Interface, LoggerPro)
- Data analysis (Excel)
- Visualization (Kaleidagraph)
- Solving ODEs numerically (Excel)

Sophomore Year:

- 24/7 access to CPL; use on own initiative
- Multisim 7 in *Electronics*
- Introduction to CPL and to computational approaches in *Computational Mechanics*
- Computational exercise in *Electromagnetic Theory*

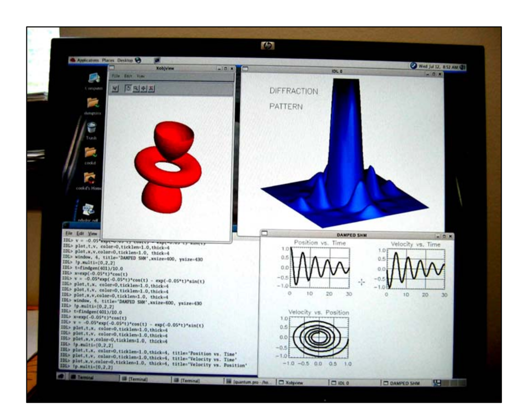
Junior/Senior Year:

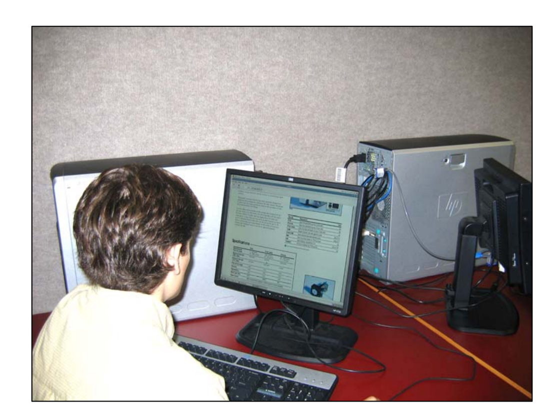
- 24/7 access to CPL
- Explicit exercises in *Quantum Mechanics* and some theory courses, depending on instructor
- On-line data acquisition and computer-based data analysis in *Advanced Laboratory*; LabView coming
- Elective course *Computational Physics*
- Student initiative in numerous courses and in tutorials, independent studies, and capstone projects
- Frequent preparation of papers and reports, both written and oral

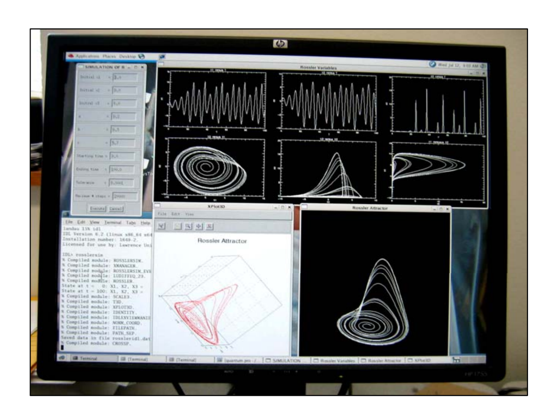
Computational Mechanics
(required of sophomores)

Catalog Description: Introduces symbolic and numerical computation through examples drawn mainly from classical mechanics but also from classical electromagnetism and quantum mechanics. This course emphasizes computer-based approaches to graphical visualization, the solution of ordinary differential equations, the evaluation of integrals, and the finding of eigenvalues and eigenvectors.
Prerequisites: *Introductory Classical Physics, Differential Equations and Linear Algebra*
Text: *Notes for Computational Mechanics* and *Computation and Problem Solving in Undergraduate Physics*, both by David M. Cook
Weekly Schedule:

WK 01	Orientation to LINUX (including text editor) Kinematics/Dynamics of Translation/Rotation Impulse/Momentum/Work/Kinetic Energy Gravity/Electromagnetic Forces/Friction/Tension
WK 02	Orientation to IDL/TGIF (basic capabilities; visualization)
WK 03	Equations of Motion (constant force/torque; force dependent only on *t*; … only on *x*, … only on *v*) Potential energy, SHM, and equilibrium Work and potential energy in 3D
WK 04	Velocity-dependent forces Damped and driven SHM Resonance Coupled and small amplitude oscillations
WK 05	HOUR EXAMINATION Orientation to LaTeX Central Forces/Effective Potential/Orbital Equation
WK 06	Planets, Satellites, Comets MID-TERM READING PERIOD
WK 07	Orientation to MAPLE Using MAPLE to Solve ODEs Algorithms to Solve ODEs Numerically
WK 08	Using IDL to Solve ODEs Numerically
WK 09	HOUR EXAMINATION Symbolic Evaluation of Integrals
WK 10	Algorithms to Evaluate Integrals Numerically Using IDL to Evaluate Integrals Numerically
WK 11	FINAL EXAMINATION







Computational Physics
(junior/senior elective)

Catalog Description: Treats computational approaches to problems in physics with particular emphasis on finite difference and finite element methods for solving partial differential equations as they arise in electromagnetic theory, fluid mechanics, heat transfer, and quantum mechanics, and on techniques for graphical visualization of the solutions.
Prerequisite: *Computational Mechanics*
Text: *Computation and Problem Solving in Undergraduate Physics* by David M. Cook
Daily Schedule:

Day 01	Programming Structures and Strategies
Day 02 **Day 03** **Day 04**	Programming in FORTRAN and IDL Analytic/Physical Derivation of PDEs (wave, diffusion, Laplace, and fluid dynamics equations) Finite Difference Methods (Part I)
Day 05 **Day 06** **Day 07**	ASSIGN DUE; Driving Programs for LSODE (Part I) Driving Programs for LSODE (Part II) No Class; Work on Assignment
Day 08 **Day 09** **Day 10**	ASSIGN DUE; Finite Difference Methods (Part II) Finite Difference Methods (Part III) No Class; Work on Assignment
Day 11 **Day 12** **Day 13**	No Class; Work on Assignment Oral Presentations on Assignment ASSIGN DUE; MUDPACK/Multigrid Techniques (Part I)
Day 14 **Day 15** **Day 16**	MUDPACK/Multigrid Techniques (Part II) No Class; Work on Assignment ASSIGN DUE; Finite Element Methods (Part I)
Day 17 **Day 18** **Day 19**	Finite Element Methods (Part II) Finite Element Methods (Part III) MID-TERM READING PERIOD; No Class
Day 20 **Day 21** **Day 22**	No Class; Work on Assignment ASSIGN DUE; FEMs with MARC/MENTAT (Part I) FEMs with MARC MENTAT (Part II)
Day 23 **Day 24** **Day 25**	Project Proposal Due; No Class; Work on Assignment Oral Presentations on Assignment Assignment Due; No Class; Start Projects
Day 26 **Day 27** **Day 28**	No Class; Work on Projects THANKSGIVING VACATION THANKSGIVING VACATION
Day 29 **Day 30** **Day 31**	No Class; Work on Projects No Class; Work on Projects Oral Presentations on Projects; Final Papers Due
	No Final Examination

Items on Table for Review

- Lawrence version of *Computation and Problem Solving in Undergraduate Physics* (*CPSUP*)
- *Solutions to Representative Exercises from CPSUP*
- *Notes for Computational Mechanics*
- *Lawrence Local Guide*
- *Introductory Classical Physics Laboratory Manual*
- *Theory of Experiment*
- Syllabi for *Computational Mechanics, Electromagnetic Theory, Quantum Mechanics, Computational Physics*

Acknowledgements and Contact

Please take a card and/or a copy of the reduced poster

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