Agenda Item #06-123
Effective Spring 2009

Eastern Illinois University
New Course Proposal
PHY 4320, Computational Physics

Please check one: ☒ New course ☐ Revised course

PART I: CATALOG DESCRIPTION

1. **Course prefix and number:** PHY 4320
2. **Title:** Computational Physics
3. **Long title:**
4. **Class hours per week, lab hours per week, and credit:** (3-3-4)
5. **Term(s) to be offered:** ☐ Fall Even Years ☒ Spring Odd Years ☐ Summer ☐ On demand
6. **Initial term of offering:** ☐ Fall ☒ Spring ☐ Summer ☐ Year 2009
7. **Course description:** This is a project-oriented course in computational physics, with an emphasis on the understanding of the computational approach to complex physics problems through detailed case studies. Topics include realistic projectile motion, oscillatory motion and chaos, the solar system, potentials and fields, waves, random systems, molecular dynamics, and quantum mechanics.

8. **Registration restrictions:**

   a. **Identify any equivalent courses**.
   b. **Prerequisite(s):** PHY 2390, PHY 3080, PHY 3410, PHY3320.
   c. **Who can waive the prerequisite(s)?**

   ☐ No one ☒ Chair ☐ Instructor ☐ Advisor ☐ Other (Please specify)

   d. **Co-requisites**:

   e. **Repeat status:** ☒ Course may not be repeated.

   f. **Degree, college, major(s), level, or class** to which registration in the course is restricted, if any:
   g. **Degree, college, major(s), level, or class** to be excluded from the course, if any:

9. **Special course attributes:**
10. **Grading methods** (check all that apply): ☒ Standard letter ☐ C/NC ☐ Audit ☐ ABC/NC
11. **Instructional delivery method:** lecture lab combined

PART II: ASSURANCE OF STUDENT LEARNING

1. List the student learning objectives of this course:
   Students will:
   - Analyze the given physics problem and identify the principal equations for the system;
   - Apply computational approach to the problem by implementing appropriate numerical methods and algorithms;
   - Evaluate the physical meaning of the computer simulation results for each project.

   a. This is not a general education course.
   b. This is not a graduate course.

2. Identify the assignments/activities the instructor will use to determine how well students attained the learning objectives:

	(35%) Laboratory projects	(25%) A midterm exam/project)	(25%) A final exam/project	(15%) Class participation
Analyze the given physics problem and identify the principal equations for the system.	X	X	X	X
Apply computational approach to the problem by implementing appropriate numerical methods and algorithms.	X	X	X	X
Evaluate the physical meaning of the computer simulation results for each project.	X	X	X	X

3. Explain how the instructor will determine students' grades for the course:

- Laboratory projects (35%)
- A midterm exam/project (25%)
- A final exam/project (25%)
- Class participation (15%)

4. *This is not a technology-delivered course.*
5. *The course number for this course is not between 4750 and 4999.*
6. *There is no writing designation for this course.*

PART III: OUTLINE OF THE COURSE

General Overview:

The class will meet in 3 fifty-minute lectures and 1 three-hour laboratory per week for 15 weeks. Lectures will be used to discuss the computational approach to various complex physics problems through case studies. Laboratory projects will be synchronized with the lecture material. Students will work in teams to analyze the project, identify the numerical methods, design computer codes, perform numerical simulations, and evaluate the simulation results.

Week 1 Introduction

- A first numerical problem-Radioactive decay
- The numerical approach
- Design and construction of a working program: codes and pseudocodes
- Testing the program and numerical considerations

Week 2 Realistic projectile motion

- Case study 1: Bicycle racing-the effect of air resistance
- Case study 2: Projectile motion-the trajectory of a cannon shell
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 3 Oscillatory motion and chaos

- Case study 1: Simple harmonic motion
- Case study 2: Realistic pendulum with dissipation, nonlinearity, and a driving force
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 4 Oscillatory motion and chaos (cont.)

- Case study 3: Chaos in the driven nonlinear pendulum
- Pseudocode and MATLAB code
- Discussion of simulation results

Week 5 Oscillatory motion and chaos (cont.)

- Routes to chaos: period doubling
- The logistic map: why the period doubles
- The Lorentz model
- Behavior in the frequency domain: chaos and noise

Week 6 The solar system

- Case study 1: Kepler's laws
- Case study 2: The inverse-square law and the stability of planetary orbits
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 7 The solar system (cont.)

- Case study 3: The three-body problem and the effect of Jupiter on Earth
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 8 Potentials and fields

- Case study 1: Electric potentials and fields: Laplace's equation
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 9 Potentials and fields (cont.)

- Case study 2: Potentials and fields near electric charges
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 10 Waves

- Case study 1: Waves (the ideal case)
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 11 Waves (cont.)

- Case study 2: Frequency spectrum of waves on a string
- Case study 3: Waves on a string (spectral methods)
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 12 Random systems

- Case study 1: Random walks
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 13 Molecular dynamics

- Case study 1: Properties of a dilute gas
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 14 Quantum mechanics

- Case study 1: Time-independent Schrödinger equation (some preliminaries)
- One dimension: shooting and matching methods
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Week 15 Quantum mechanics (cont.)

- A matrix approach and a variational approach
- Case study 2: Time-dependnet Schrödinger equation (direct solutions)
- Pseudocodes and MATLAB codes
- Discussion of simulation results

Finals week: Final exam.

PART IV: PURPOSE AND NEED

1. Explain the department's rationale for developing and proposing the course.
   - Physics majors seeking a career in computational physics need not only to be familiar with the various numerical methods and their applications in *simple* systems, but also need to have an exposure to the computational approach to many modern topics and hence more *complex* systems that are of current interest to physicists. The newly proposed course PHY 3320 aims at the former and the currently proposed course PHY 4320 satisfies the latter. This course focuses on the computational approach to the solution of more complex systems in physics. Topics that will be covered include mechanics, potentials and fields, random systems, molecular dynamics, and quantum mechanics. Students will gain a solid understanding of the computational approach to each topic through detailed case studies. Besides regular lectures, students work in teams on projects in the laboratory and hence gain valuable experience in computer modeling and simulation.

   a. *This is not a general education course.*
   b. *This is not a graduate course.*

2. Justify the level of the course and any course prerequisites, co-requisites, or registration restrictions.
   - This course is designed to be an upper-level course for physics majors and minors and it is appropriate to be at the 4000 level. Since this course deals with topics in mechanics, potentials and fields, and quantum mechanics, students are expected to have a working knowledge in these areas, and therefore students must have completed PHY 2390 (Statics), PHY 3080 (Modern Physics I), and PHY 3410 (Electricity and Magnetism I). Moreover, students must have an understanding of the various numerical methods and their applications in *simple* systems in order to understand the computational approach to more *complex* systems. Therefore, PHY 3320 (Computational Methods in Physics and Engineering) is also required.

3. If the course is similar to an existing course or courses, justify its development and offering.
   a. *This course does not overlap with any existing course within the Physics Department or any other program.*
   b. No course will be deleted if this course is approved. This course is required in the new Computational Physics Option.

4. Impact on Program(s):
   - Required for undergraduate Physics majors who have chosen the Computational Physics option; Elective for undergraduates in Physics minor.

PART V: IMPLEMENTATION

1. Faculty member(s) to whom the course may be assigned:
   - This course will be initially taught by Dr. Jie Zou but can be taught by other faculty members in the Physics Department who have background in computational physics.
2. Additional costs to students:
   - There are no additional course fees.

3. Text and supplementary materials to be used (Include publication dates):
    - Text: *Computational Physics*, by Nicholas J. Giordano and Hisao Nakanishi, 2nd edition, 2006. Pearson Prentice Hall, Pearson Education, Inc., Upper Saddle River, NJ.

PART VI: COMMUNITY COLLEGE TRANSFER

A community college course will not be judged equivalent to this course.

PART VII: APPROVALS

Date approved by the Physics Department: ____________________________October 16th, 2006_____

Date approved by the College of Sciences Curriculum Committee ________November 17th, 2006___

Date approved by CAA _______December 7th, 2006