Agenda Item #06-121
Effective Spring 2008

Eastern Illinois University
New Course Proposal
PHY 3320, Computational Methods in Physics and Engineering

Please check one: ☒ New course ☐ Revised course

PART I: CATALOG DESCRIPTION

1. **Course prefix and number:** PHY 3320
2. **Title:** Comp Methods in Phy and Engr
3. **Long title:** Computational Methods in Physics and Engineering
4. **Class hours per week, lab hours per week, and credit:** (3-3-4)
5. **Term(s) to be offered:** ☐ Fall ☒ Spring Even ☐ Summer ☐ On demand
6. **Initial term of offering:** ☐ Fall ☒ Spring ☐ Summer ☐ Year 2008
7. **Course description:** An introduction to various numerical methods for solution of nonlinear equations, numerical differentiation, solution of ordinary differential equations for both initial-value and boundary-value problems. This course focuses on practical applications of these methods in simple physics and engineering systems and hands-on experience with computer modeling and simulation.
8. **Registration restrictions:**

   a. **Identify any equivalent courses**

   b. **Prerequisite(s):** PHY 1371, MAT 2170, Concurrent or prior enrollment in MAT 2550.

   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:
   - Identify and describe the principles of various numerical methods for a given problem;
   - Apply numerical methods to solve problems in simple physics and engineering systems;
   - Apply programming skills to perform computer simulations;
   - Analyze simulation results and compare the strengths of different numerical methods.

   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:

	(20%) Homework and quizzes	(30%) Midterm exam and final exam	(40%) Laboratory projects	(10%) Class participation
Identify and describe the principles of various numerical methods for a given problem	X	X	X	X
Apply numerical methods to solve problems in simple physics and engineering systems	X	X	X	X
Apply programming skills to perform computer simulations			X	X
Analyze simulation results and compare the strengths of different numerical methods			X	X

3. Explain how the instructor will determine students' grades for the course:
   - Homework and quizzes (20%)
   - Midterm exam and final exam (30%)
   - Laboratory projects (40%)
   - Class participation (10%)
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 describe the principles of different numerical methods and discuss their applications in simple physics and engineering systems. Laboratory projects will be synchronized with the lecture material. Students will identify numerical methods, design computer algorithms, and perform numerical simulations.

Week 1 Introduction
- What is computational science, and why is it important?
- Overview: computers, computer programming, available software, data representation and numerical methods considered
- Introduction to MATLAB

Week 2 Solution of nonlinear equations
- Incremental search method
- Bisection method

Week 3 Solution of nonlinear equations (cont.)
- Newton-Raphson method
- Secant method

Week 4 Solution of nonlinear equations (cont.)

- Comparison of various methods
- Applications in solving physics and engineering problems

Week 5 Numerical differentiation

- Basic finite-difference approximations
- Taylor's series expansion approach

Week 6 Numerical differentiation (cont.)

- Applications in solving physics and engineering problems

Week 7 Numerical integration

- Newton-Cotes formulas (rectangular method and trapezoidal method)
- Simpson method

Week 8 Numerical integration (cont.)

- Gauss quadrature

Week 9 Numerical integration (cont.)

- Comparison of various methods
- Applications in solving physics and engineering problems

Week 10 Ordinary differential equations: initial value problems

- Euler's method
- Higher order Taylor's series method

Week 11 Ordinary differential equations: initial value problems (cont.)

- Runge-Kutta method
- Multistep method
- Adams method
- Predictor-corrector method

Week 12 Ordinary differential equations: initial value problems (cont.)

- Comparison of various methods
- Applications in solving physics and engineering problems

Week 13 Ordinary differential equations: boundary-value problems

- Shooting method
- Finite-difference method

Week 14 Ordinary differential equations: boundary-value problems (cont.)

- Solution of eigen-value problems

Week 15 Ordinary differential equations: boundary-value problems (cont.)

- Comparison of various methods
- Applications in solving problems in physics and engineering

Finals week: Final exam.

PART IV: PURPOSE AND NEED

1. Explain the department's rationale for developing and proposing the course.
    - According to a recent study conducted by the IEEE Computer Society and the American Institute of Physics for a special theme issue of *Computing in Science and Engineering* (*CiSE*), it is believed that "physics education must come to grips with the reality that computation is becoming an indispensable tool in every scientific and engineering field, and that as a custodian of scientific literacy, physics must respond to this reality." Despite the growing significance of computation in physics curricula, very few universities in the state of Illinois currently offer a computational methods course at the undergraduate level specifically for physics and engineering majors. This course will become a unique offering for our physics and pre-engineering students. It emphasizes the application of numerical methods to solving physics and engineering problems. Additionally, the laboratory component of the course allows students to gain hands-on experience with the latest scientific computing software, such as MATLAB, for simulation and visualization.

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 an intermediate-level undergraduate course designed for physics majors and minors. A 3000-level is appropriate. Students are expected to have the relevant physics background at the level of the General Physics sequences up to PHY 1371 (General physics III). Additionally, in order to successfully complete the lab exercises, students should be familiar with basics in computer programming (MAT 2170 Computer Science I). Since this course deals with topics in linear algebra MAT 2550 (Introduction to Linear Algebra) is required.

3. If the course is similar to an existing course or courses, justify its development and offering.
   a. This course does not *significantly* overlap with any existing course within the Physics Department or any other program. Although MAT 3570 (Numerical Calculus) covers *some* similar topics in numerical methods, this course is particularly geared towards physics and pre-engineering majors, with an emphasis on the practical applications of the methods in solving physics and engineering problems that students may encounter in their future study. The textbook that is proposed for this course is entitled "*Applied Numerical Methods for Engineers and Scientists*", which satisfies this need and is a different book from that used in MAT 3570.

   b. No courses 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 major and 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 science.

2. Additional costs to students:
   - There are no additional course fees.

3. Text and supplementary materials to be used (Include publication dates):
   - Text: *Applied Numerical Methods for Engineers and Scientists*, by Singiresu S. Rao, 2002. Prentice-Hall, Inc., Upper Saddle River, New Jersey.

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