Course Syllabus
Southeast Missouri State University

Department of Physics | **Course No. PH370/PH503**
Title of Course: Mechanics | **Revision: Spring 1999**

I. Catalog Description

Selected topics in Newtonian mechanics, including kinematics and dynamics of particles, oscillations, gravitation, Lagrangian and Hamiltonian dynamics, central-force motion, noninertial reference frames, and rigid body dynamics. Fall of even years only. Prerequisites: PH231/031; MA245. (3)

II. Prerequisites

PH231/PH-031 General Physics II
MA245 Vector Calculus

III. Course Objectives

A. To provide students with fundamental knowledge of Newtonian mechanics, including the topics of kinematics and dynamics of particles, oscillations, gravitation, Lagrangian and Hamiltonian dynamics, central-force motion, noninertial reference frames, and rigid body dynamics.

B. To introduce students to advanced mathematical techniques (such as solving second-order linear differential equations, series expansion of functions, vector field theory, etc.) which are commonly encountered in classical mechanics and other branches of physics.

C. To acquaint students with the availability of reference material such as the various handbooks and tables of mathematical functions, computational software (MathCad, DERIVE, etc.), and internet URL's devoted to physics-related data.

IV. Expectations of Students

A. All Students
   1. Attend class regularly, participate in classroom discussions, work all assigned homework problems, and demonstrate competence in the subject matter by performing satisfactorily on examinations.
   2. Develop the ability to solve mechanics problems utilizing the analytical methods learned in the course.
   3. Demonstrate originality in the solutions of selected problems through the use of reference materials.

B. Graduate Students - Demonstrate research ability by submitting an original term project on some aspect of mechanics. The project will be computational in nature and the student is expected to draw inferences from the results of the work. The project will be on a topic mutually agreed upon by the student and the instructor before mid-semester with the project being due one week before the final exam.

V. Course Outline (Hours)

A. VECTOR ANALYSIS (2)
   1. Unit vectors
   2. Dot and cross product
   3. Kinematics - position, velocity, acceleration vectors in common coordinate systems

B. NEWTONIAN MECHANICS-SINGLE PARTICLE (9)
   1. Newton's three laws of motion - interpretation and application
   2. Concepts of mass, acceleration, and force
   3. Free-body diagrams
   4. Retarding forces - air resistance, etc.
   5. Free-fall and projectile motion
      a. Analytical results
      b. Numerical results
   6. Energy and momentum conservation theorems
   7. Potential energy and equilibrium
   8. Rocket motion

C. HOUR EXAMINATION (1)

D. OSCILLATIONS (5)
   1. Simple harmonic motion (SHM)
      a. Definitions
      b. Equation of motion and solution
      c. Energy considerations
      d. Speed-distance relation
   2. Phase diagrams
   3. Damped oscillations
      a. Equation of motion
      b. Solutions for underdamped, critically damped, and overdamped motion
      c. Graphs of the 3 cases for different initial conditions
      d. Examples in nature
   4. Driven damped oscillator
      a. Equation of motion
      b. Physical interpretation of the solution (transient + steady-state)
      c. Graphs of the transient and steady-state solutions
      d. Resonance phenomena
      e. Dependence of amplitude and phase angle on the quality factor Q
      f. Electrical oscillations

E. GRAVITATION (3)
   1. Newton's law of universal gravitation

2. Gravitational quantities
    a. Gravitational force
    b. Gravitational potential energy
    c. Gravitational field
    d. Gravitational potential
3. Calculation of gravitational quantities for specific geometries
    a. Point masses
    b. Spherically symmetric mass distributions
    c. Generalized mass distributions

F. LAGRANGIAN DYNAMICS (4)
1. Calculation of kinetic energy in various coordinate systems (rectangular, polar, etc.)
2. Calculation of potential energy for a given conservative force
3. Lagrangian and generalized coordinates
4. Lagrange equations of motion

G. HOUR EXAMINATION (1)

H. CENTRAL FORCE MOTION (5)
1. Two-body problem (reduced mass)
2. Equation of motion in polar coordinates for central-force motion
3. Energy equation for central-force motion
4. Equation of the orbit for inverse-square forces
5. Bound orbits (circle, ellipse) and unbound orbits (parabola, hyperbola)
6. Energy equations for bound orbits
    a. Energy-eccentricity relation
    b. Speed-distance relation
7. Ellipse geometry
8. Kepler's Laws
9. Orbital dynamics (Hohmann transfer)

I. DYNAMICS OF A SYSTEM OF PARTICLES (4)
1. Definition of the center of mass (CM)
2. Relationships involving motion of CM and motion relative to CM
3. Energy and momentum conservation theorems
4. Elastic collisions of two particles (conservation of kinetic energy and momentum)
5. Inelastic collisions of two particles
    a. Conservation of total energy and momentum
    b. Coefficient of restitution
    c. Q-value of collision
6. Collisions of two particles in LAB and CM systems

J. HOUR EXAMINATION (1)

K. NONINERTIAL REFERENCE FRAMES (4)
1. Definitions of inertial and noninertial reference frames

2. Definitions of real and fictitious forces
3. Translating reference frames - description of motion as seen by inertial and noninertial observers
4. Rotating reference frames
    a. Centrifugal and Coriolis forces
    b. Description of motion as seen by inertial and noninertial observers
5. Motion on the rotating Earth
    a. Gravitational g and effective g
    b. Deviation of a plumb bob from the vertical
    c. Centrifugal and Coriolis forces
    d. Motion of an object in free fall
    e. Motion of a projectile

L. RIGID BODY DYNAMICS (5)
1. Definition of center of mass (CM)
2. Relationships involving motion of CM and motion relative to CM
    a. Translational kinetic energy
    b. Rotational kinetic energy
    c. Angular momentum
3. Moment of inertia and parallel axis theorem
4. Rolling motion of spheres and cylinders on different surfaces
5. Inertia tensor
6. Principal moments of inertia and principal axes of inertia
7. Stability of rigid-body rotations

M. HOUR EXAMINATION (1)

TOTAL HOURS: 45

VI. Textbooks and Other Required Material

A. *Classical Dynamics of Particles and Systems* by Jerry B. Marion and Stephen T. Thornton (4th edition, 1995, Saunders College Publishing).

B. Computers in the Physics Department will be available for students to utilize computational software such as MATHCAD, DERIVE, etc.

VII. Basis for Student Evaluation

A. Undergraduate students
1. Tests (3 @ 20% each) - 60%
2. Final exam - 20%
3. Homework - 20%

Total - 100%

B. Graduate students
1. Tests (3 @ 18% each) - 54%
2. Final exam - 18%

3. Homework - 18%
4. Term project - 10%

Total - 100%