

COURSE SCALE LEARNING GOALS

Math Methods with Classical Mechanics – Second Semester (Phys 3210)

These learning goals are a work in progress, to be replaced by a more comprehensive set of goals developed by faculty in physics education research and those with experience teaching the course. They are a slight extension of the set designed for the first-semester course, PHYS 2210. This list represents what we want students to be able to *do* at the end of the course (as opposed to what *content* is expected to be covered, as in a syllabus).

1. **Math/physics connection:** Students should be able to translate a physical description of a sophomore-level classical mechanics problem to a mathematical equation necessary to solve it. Students should be able to explain the physical meaning of the formal and/or mathematical formulation of and/or solution to a sophomore-level physics problem. Students should be able to achieve physical insight through the mathematics of a problem.
2. **Visualize the problem:** Students should be able to sketch the physical parameters of a problem including sketching the physical situation and the coordinates (e.g. , equipotential lines, a resonance curve, a pendulum with its angle as the coordinate,) as appropriate for a particular problem.
3. **Expecting and checking solution:** When appropriate for a given problem, students should be able to articulate their expectations for the solution to a problem, such as direction of a force, dependence on coordinate variables, and behavior at large distances or long times. For all problems, students should be able to justify the reasonableness of a solution they have reached, by methods such as checking the symmetry of the solution, looking at limiting or special cases, relating to cases with known solutions, checking units, dimensional analysis, and/or checking the scale/order of magnitude of the answer.
4. **Organized knowledge:** Students should be able to articulate the big ideas from each chapter, section, and/or lecture, thus indicating that they have organized their content knowledge. They should be able to filter this knowledge to access the information that they need to apply to a particular physical problem, and make connections/links between different concepts.
5. **Communication.** Students should be able to justify and explain their thinking and/or approach to a problem or physical situation, in either written or oral form. Students should be able to write up problem solutions that are well-organized, clear, and easy to read.

6. **Build on Earlier Material.** Students should deepen their understanding of Phys 1110 material. I.e., the course should build on earlier material.
7. **Problem-solving techniques:** Students should continue to develop their skills in choosing and applying the problem-solving technique that is appropriate to a particular problem. This indicates that they have learned the essential features of different problem-solving techniques (eg., solving differential equations with constant coefficients, using Fourier series methods to solve PDEs with appropriate boundary conditions, etc). They should be able to apply these problem-solving approaches to novel contexts (i.e., to solve problems which do not map directly to those in the book), indicating that they understand the essential features of the technique rather than just the mechanics of its application. Students should move away from using templates. They should be able to justify their approach for solving a particular problem.

...7a. Vectors and coordinate systems: Students should be able to compute dot and cross products and solve vector equations without reference to books or external materials, and they should demonstrate comfort with these mathematical tools. Students should recognize whether variables are scalars or vectors, and vector and scalar variables should be clearly distinguishable in students' written work. Students should be able to project a given vector into components in multiple coordinate systems, and to choose the most appropriate coordinate system in order to solve a given problem. Students should be able to compute surface and volume integrals in Cartesian, cylindrical, and spherical coordinate systems (i.e., know the expressions for dV in these coordinate systems and how to apply them in a particular situation).

...7b. Approximations: Students should be able to recognize when approximations are useful, and use them effectively (eg., recognize when air resistance is a small effect, Students should be able to indicate how many terms of a series solution must be retained to obtain a solution of a given order, and should be able to identify when a Taylor expansion is appropriate and what the variable of expansion is in a given problem.

...7c. Series expansions: Students should be able to recognize when a series expansion is appropriate to approximate a solution, and expand a Taylor Series beyond zeroth order.

...7d. Orthogonality: Students should recognize that both vectors and functions can be orthogonal and that any function can be built from a complete orthonormal basis. Students should be able to expand functions in an orthonormal basis (e.g. find the coefficients for a Fourier series) and interpret the coefficients physically. Students should be able to determine from the even or odd symmetry of a function which terms in the expansion are zero. Students should be able to define the terms complete and

orthonormal in the context of an orthonormal basis.

...7e. Differential equations: Given a physical situation, students should be able to write down the required ordinary differential equation, identify the method of solution, and correctly calculate the answer. Students should be able to identify the type of differential equation (homogeneous, linear vs. nonlinear, constant vs. variable coefficients, 1st, 2nd, or higher order, etc.) and choose the correct method to solve that type of ODE. Students should be able to explain how the type of differential equation helps determine which methods of solution will be applicable.

...7f. Superposition: Students should recognize that – in a linear system – the solutions may be formed by superposition of components.

...7g. Matrix representation: Students should be able to recognize when matrices are appropriate in descriptions of a physical system, including as physical properties of an object (such as the inertia tensor), or as mathematical descriptions of a system (linear operators such as rotation, or description of a system of objects for solution of coupled differential equations.)

- 8. Problem-solving strategy:** Students should be able to draw upon an organized set of content knowledge (LG#3), and apply problem-solving techniques (LG#4) to that knowledge in order to organize and carry out long analyses of physical problems. They should be able to connect the pieces of a problem to reach the final solution. They should recognize that wrong turns are valuable in learning the material, be able to recover from their mistakes, and persist in working to the solution even though they don't necessarily see the path to the solution when they begin the problem. Students should be able to articulate what it is that needs to be solved in a particular problem and know when they have solved it.
- 9. Intellectual maturity:** Students should accept responsibility for their own learning. They should be aware of what they do and don't understand about physical phenomena and classes of problem. This is evidenced by asking sophisticated, specific questions; being able to articulate where in a problem they experienced difficulty; and take action to move beyond that difficulty.

TOPIC SCALE LEARNING GOALS

3210 Topic-level learning goals. (There is some copy-paste from course-scale learning goals when appropriate).

Topics covered in 3210:

Math	Physics contexts
Calculus of variations	Lagrangian mechanics
	Central Forces and Orbits
	Non-inertial reference frames
Linear algebra: Trace and determinant, linear operators, change of basis	Rigid body rotation
Eigenvalues and eigenvectors: diagonalization	Rigid body rotation
Systems of ODEs: use of eigenvalue/eigenvector methods	Coupled Oscillations
Nonlinear differential equations: numerical methods	Hamiltonian mechanics and chaos
	Continuum mechanics (or other advanced topics, at the discretion of the instructor)

Goals:

(to be filled in after consultation with PRE and other instructors.)