**COURSE SCALE LEARNING GOALS**
**E&M 1**

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These learning goals were created by a working group of faculty – both those in physics education research and those with other areas of research. 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).

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1. **Math/physics connection:** Students should be able to translate a physical description of a junior-level electromagnetism 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 junior-level electromagnetism 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 (e.g., E or B field, distribution of charges, polarization), as appropriate for a particular problem.

3. **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.

4. **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.

5. **Problem-solving techniques:** Students should be able to choose and apply 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., separation of variables, method of images, direct integration). 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. They should be able to justify their approach for solving a particular problem.

   **…5a. Approximations:** Students should be able to recognize when approximations are useful, and use them effectively (eg., when the observer is very far away from or very close to the source). Students should be able to

indicate how many terms of a series solution must be retained to obtain a solution of a given order.

**…5b. Series expansions:** Students should be able to recognize when a series expansion is appropriate to approximate a solution, and complete a Taylor Series to two terms.

**…5c. Symmetries:** Students should be able to recognize symmetries and be able to take advantage of them in order to choose the appropriate method for solving a problem (eg., when to use Gauss' Law, when to use separation of variables in a particular coordinate system).

**…5d. Integration:** Given a physical situation, students should be able to write down the required partial differential equation, or line, surface or volume integral, and correctly calculate the answer.

**…5e. Superposition:** Students should recognize that – in a linear system – the solutions may be formed by superposition of components.

6. **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.

7. **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 the field, dependence on coordinate variables, and behavior at large distances. 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.

8. **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.

9. **Maxwell's Equations.** Students should see the various laws in the course as part of the coherent field theory of electromagnetism; ie., Maxwell's equations.

10. **Build on Earlier Material.** Students should deepen their understanding of Phys 1120 material. I.e., the course should build on earlier material.

## OVERALL COURSE OBJECTIVES:
## CALCULATION AND COMPUTATION

Students will be able to:

- Compute gradient, divergence, curl, and Laplacian
- Evaluate line, surface, and volume integrals
- Apply the fundamental theorem for divergences (Gauss' Theorem) in specific situations
- Apply the fundamental theorem for curls (Stoke's Theorem) in specific situations
- Apply Coulomb's Law and superposition principle to calculate electric field due to a continuous charge distribution (uniformly charged line segment, circular or square loop, sphere, etc.)
- Apply Gauss' Law to compute electric field due to symmetric charge distribution
- Calculate electric field from electric potential and vice versa
- Compute the potential of a localized charge distribution
- Determine the surface charge distribution on a conductor in equilibrium
- Use method of images to determine the potential in a region
- Solve Laplace's equation to determine the potential in a region given the potential or charge distribution at the boundary (Cartesian, spherical and cylindrical coordinates)
- Use multipole expansion to determine the leading contribution to the potential at large distances from a charge distribution
- Calculate the field of a polarized object
- Find the location and amount of all bound charges in a dielectric material
- Apply Biot-Savart Law and Ampere's Law to compute magnetic field due to a current distribution
- Compute vector potential of a localized current distribution using multipole expansion
- Calculate magnetic field from the vector potential
- Calculate the field of a magnetized object
- Compute the bound surface and volume currents in a magnetized object
- Compute magnetization, H field, susceptibility and permeability