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Model-Based Reasoning in Upper-division Lab Courses

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Modeling, which includes developing, testing, and refining models, is a central activity in physics. Well-known examples from AMO physics include everything from the Bohr model of the hydrogen atom to the Bose–Hubbard model of interacting bosons in a lattice. Modeling, while typically considered a theoretical activity, is most fully represented in the laboratory where measurements of real phenomena intersect with theoretical models, leading to refinement of models and experimental apparatus. However, experimental physicists use models in complex ways and the process is often not made explicit in physics laboratory courses. We have developed a framework to describe the modeling process in physics laboratory activities. The framework attempts to abstract and simplify the complex modeling process undertaken by expert experimentalists. The framework can be applied to understand typical processes such the modeling of the measurement tools, modeling "black boxes," and signal processing. We demonstrate that the framework captures several important features of model-based reasoning in a way that can reveal common student difficulties in the lab and guide the development of curricula that emphasize modeling in the laboratory. We also use the framework to examine troubleshooting in the lab and guide students to effective methods and strategies.