18.S: The Transition to Quantum Physics (Summary)

The important point of this discussion is that variational formulations of classical mechanics provide a rational, and direct basis, for the development of quantum mechanics. It has been shown that the final form of quantum mechanics is closely related to the Hamiltonian formulation of classical mechanics. Quantum mechanics supersedes classical mechanics as the fundamental theory of mechanics in that classical mechanics only applies for situations where quantization is unimportant, and is the limiting case of quantum mechanics when $\hbar \to 0$ which is in agreement with the Bohr's Correspondence Principle. The Dirac relativistic theory of quantum mechanics is the ultimate quantal theory for the relativistic regime.

This discussion has barely scratched the surface of the correspondence between classical and quantal mechanics, which goes far beyond the scope of this course. The goal of this chapter is to illustrate that classical mechanics, in particular, Hamiltonian mechanics, underlies much of what you will learn in your quantum physics courses. An interesting similarity between quantum mechanics and classical mechanics is that physicists usually use the more visual Schrödinger wave representation in order to describe quantum physics to the non-expert, which is analogous to the similar use of Newtonian physics in classical mechanics. However, practicing physicists invariably use the more abstract Heisenberg matrix mechanics to solve problems in quantum mechanics, analogous to widespread use of the variational approach in classical mechanics, because the analytical approaches are more powerful and have fundamental advantages. Quantal problems in molecular, atomic, nuclear, and subnuclear systems, usually involve finding the normal modes of a quantal system, that is, finding the eigen-energies, eigen-functions, spin, parity, and other observables for the discrete quantized levels. Solving the equations of motion for the modes of quantal systems is similar to solving the many-body coupled-oscillator problem in classical mechanics, where it was shown that use of matrix mechanics is the most powerful representation. It is ironic that the introduction of matrix methods to classical mechanics is a by-product of the development of matrix mechanics by Heisenberg, Born and Jordan. This illustrates that classical mechanics not only played a pivotal role in the development of quantum mechanics, but it also has benefitted considerably from the development of quantum mechanics; that is, the synergistic relation between these two complementary branches of physics has been beneficial to both classical and quantum mechanics.

Recommended reading

"Quantum Mechanics" by P.A.M. Dirac, Oxford Press, 1947,

"Conceptual Development of Quantum Mechanics" by Max Jammer, Mc Graw Hill 1966.