Section 12.1: Introducing Quantum Theory

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1. In classical physics, energy can be transferred by collisions between particles and larger objects, including near-collisions when objects interact at a distance (e.g., charged particles, astronomical objects) and by waves, including water waves, sound, and light.

2. Classical particles differ from classical waves in that a particle occupies a small region of space with some mass density that abruptly changes outside the particle. In contrast, a wave spreads out over a large region and oscillates. Also, for transferring energy, particles tend to transfer energy in discrete parcels (lumps), one at a time, whereas waves continuously transfer energy and can interfere destructively.

3. (a) The double-slit experiment with electrons shows that the energy arrives in discrete lumps, which indicates that the electrons are particles.

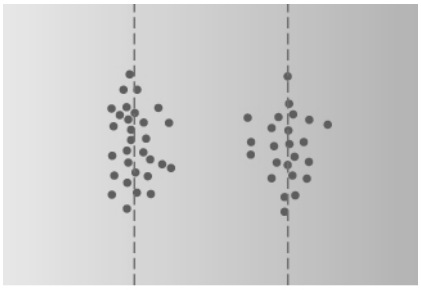
(b) The double-slit experiment with electrons also shows destructive interference, which indicates that the electrons are waves.

4. In the early twentieth century, classical physics could describe nearly everything physical. However, there were a few puzzling things related to microscopic phenomena, particularly the behaviour of atoms and electrons, that disagreed with predictions of classical physics. Atoms and electrons behave differently than large objects such as baseballs, rockets, and planets. In particular, microscopic objects can exhibit wave-like behaviour. Quantum theory was developed to describe both the wave-like and particle-like behaviour of microscopic things such as atoms and electrons.

5. The electron double-slit experiment showed that electrons can interfere like waves, which is a non-classical behaviour. The result could not be explained by classical physics and thus gave a major push to the development of quantum theory.

6. Quantum theory is more complete than Maxwell's theory because it can describe both the wave-nature and the particle-nature of light. Maxwell's theory describes only the wave-nature of light.

7. Golf balls hit toward a wall with two narrow slits would leave a distribution of marks on a wall behind the slits. The distribution would show two dense areas directly behind each slit. Many balls would not even hit the slits, but assuming that a high fraction of them did, the distribution would look like the one below.



Possible distribution of marks
left by golf balls passing through two slits

8. (a) The distribution of baseballs behind the two open slits would look similar to (b).

(b) The distribution of electrons behind the two open slits would look similar to (a). (The slits would have to be narrower in accordance with the smaller size of the electrons.)

9. Some of our intuitions gained through our experiences in the macroscopic world of large objects do not apply to the quantum world because objects in the quantum world exhibit both wave-like and particle-like behaviour. Things in the macroworld exhibit only wave-like or particle-like behaviour.