

1.8 All is not well with the classical viewpoint

There is a persistent fiction that it was widely believed that physicists near the end of the 19th century thought that they knew all of the fundamental physics and all that was left was to make more precise calculations. This sort of statement has been attributed to Lord Kelvin. The reality is that lots of people worried about problems with the fundamental ideas not exactly describing the results of experiments. In some cases the theories contradict each other. As we will see, there were many problems the many people were deeply concerned about.

The luminiferous ether is a hypothesized non-interacting substance that was believed to permeate all of space. This was the medium through which light, electricity, and magnetism propagated through space. Since it permeated everywhere, it could not be interacting with any normal matter or no planetary orbits would be stable (they would cause a planet to slow through friction, and all planets would then spiral into the Sun).

Albert Michelson and Edward Morley performed a fateful experiment. This experiment was a way of using the classical theory of light waves to determine the motion of the Earth through the luminiferous ether. Without going into details here, they found nothing. Theoretical efforts were made to explain the lack of a result. Others tried the same and similar experiments, but to no avail. The theoretical physicists Hendrik Lorentz and George FitzGerald suggested that motion through the ether contracted objects along the direction of motion. It was a very weird theory to explain the lack of any luminiferous ether—physicists in the late 1800s loved their luminiferous ether!

Right around the turn of the century Henri Poincaré developed a theory of the motion of three bodies—the famous three-body problem—that seemed to set classical physics on its head. The basic foundation of classical physics, as we already noted, is determinism. The equations allow you to determine the motion of a system into the future. However, Poincaré discovered that in the three-body problem it rapidly develops that the motions cannot be predicted. The solution branches off into more than one possibility, and it is not possible to predict which solution will be taken by the three bodies. This process of a single solution splitting into two is called *bifurcation*. When bifurcations occur with increasing frequency, the system is said to exhibit *chaos*.

One of the theories of classical physics is that of the quantity of heat required to raise the temperature of some material—its heat capacity. It is a very detailed theory and makes precise predications. Jeans and Maxwell both found this theory to be completely wrong. In fact, this was the first instance of someone discovering that a classical theory was completely wrong.

John Dalton renewed a theory originally posed by Democritus of ancient Greece, that matter is composed of atoms. These were thought to be indivisible. All of elementary chemistry is based on the elements being atoms. Many people do not realize that the existence of atoms was not completely proven until early in the 20th century (by Albert Einstein).

Robert Brown, a British biologist, discovered that microscopic particles vibrate. No one could figure out why this occurred. It was a great mystery that was completely beyond classical physics.

In 1897 J. J. Thompson discovered the first known subatomic particle. This was called the *electron*. It was the first indication that there was some structure to the atom. This triggered many models of this structure, none of which were able to describe the stability of the electron. In 1909 an experiment by Ernest Rutherford, Hans Geiger, and Ernest Marsden established that there was a central nucleus of the atom. Following this Rutherford developed a model of the atom that is similar to a solar system—which everyone knew could not be true, since the electrons orbiting the nucleus would radiate their energy away and spiral into the nucleus. The fact that this did not happen was direct evidence that classical physics could not be true.

The idea of breaking light into a spectrum was well known in the 1800s, even Isaac Newton had experimented with breaking light into a spectrum with a prism. It was learned that heating atoms to emit light forced them to give off light at specific points in the spectrum. These were the line spectra of atoms, and allowed atoms to be identified. It was discovered by Pieter Zeeman that spectral lines broke up into component lines by a magnetic field, and Jonannes Stark that a similar effect occurred with electric fields. These became known respectively as the Zeeman and Stark effects. Again, classical physics could not accurately account for these effects.

In 1859 Gustav Kirchhoff used the term blackbody radiation to describe the strange relationship between the intensity and wavelength of light at specific temperatures (see Figure 1). Try as they might, no one could figure out why this curve had the shape it had. Different people could derive different parts of the curve, but no classical theory could account for all of it.

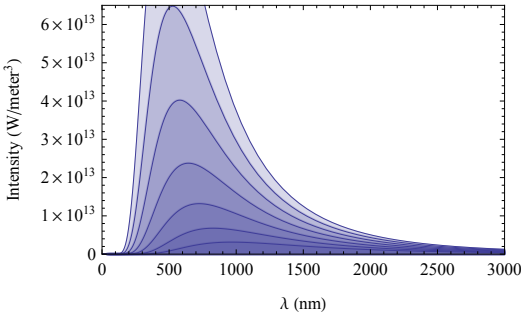


Figure 1: The Blackbody Radiation Curve at Different Temperatures.

Thus it was that the seeds of the overthrow of the classical theories of physics were sown deep within the mysteries of the world. On every front, as we will see, the assumptions of classical physics fell. The absolute nature of time and of distance, and the assumption of determinism—those things that we take for granted—are simply not true!

You might ask, reasonably enough, why we study these things if they are not true. Think of it as constructing a high building. We build a scaffolding around the developing structure. When the new building is finished, the scaffolding—no longer important—is removed. Thus it is for classical physics—the real world is not truly the realm of applicability of these classical laws. Despite this, there are many phenomena for which the classical laws are a reasonable approximation. Also the classical laws provide us, in many cases, with

simple models that allow us to practice the experimentsl, mathematical, and computational techniques we will surely need later. It also develops physical intuitions that might guide us.