THE CONCEPT OF PROBABILITY IN QUANTUM MECHANICS

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From about the beginning of the twentieth century experimental physics amassed an impressive array of strange phenomena which demonstrated the inadequacy of classical physics. The attempts to discover a theoretical structure for the new phenomena led at first to a confusion in which it appeared that light, and electrons, sometimes behaved like waves and sometimes like particles. This apparent inconsistency was completely resolved in 1926 and 1927 in the theory called quantum mechanics. The new theory asserts that there are experiments for which the exact outcome is fundamentally unpredictable, and that in these cases one has to be satisfied with computing probabilities of various outcomes. But far more fundamental was the discovery that in nature the laws of combining probabilities were *not* those of the classical probability theory of Laplace.

I want to discuss here the laws of probability of quantum mechanics. The subject is over twenty years old and has been expertly discussed in many places. My only excuse for speaking about it again is the hope that, being mathematicians, all of you may not have heard of it in detail. And you may be delighted to learn that Nature with her infinite imagination has found another set of principles for determining probabilities; a set other than that of Laplace, which nevertheless does not lead to logical inconsistencies. We shall see that the quantum mechanical laws of the physical world approach very closely the laws of Laplace as the size of the objects involved in the experiments increases. Therefore, the laws of probabilities which are conventionally applied are quite satisfactory in analyzing the behavior of the roulette wheel but not the behavior of a single electron or a photon of light.

I should say, that in spite of the implication of the title of this talk the concept of probability is not altered in quantum mechanics. When I say the probability of a certain outcome of an experiment is p, I mean the conventional thing, that is, if the experiment is repeated many times one expects that the fraction of those which give the outcome in question is roughly p. I will not be at all concerned with analyzing or defining this concept in more detail, for no departure from the concept used in classical statistics is required.

What is changed, and changed radically, is the method of calculating probabilities. The effect of this change is greatest when dealing with objects of atomic dimensions. For this reason we shall illustrate the laws of quantum mechanics by describing the results to be expected in some experiments dealing with a single electron. The experiment is illustrated in figure 1.

At A we have a source of electrons S. The electrons at S all have the same