(b). The designer must account for the rate of change in the internal energy of the balls. In solids, this results primarily from changes in amplitude of vibration of the molecules about their fixed positions within the crystal. Since the engineer must obtain information concerning these motions, he chooses the molecules as the particles.

Notice the player is unconcerned about the finer detail of the internal structure of the balls. The designer is similarly unconcerned about the finer detail of the structure of the molecule. Each has chosen the largest particle consistent with the question to which he sought an answer.

A further difference between the perspective of the player and the designer is the detail of their study of the chosen particles. The pool player endeavors to understand the details of the motion of each ball on every shot—deterministic mechanics. The designer, on the other hand, is not interested in the detailed behavior of individual molecules. He seeks a general knowledge of the collective behavior of the group, or of the *typical* behavior of the individual.[1] This latter perspective is the method of Statistical Mechanics.

In Exmp. 1 it was possible to select a single type of particle (the balls, the molecules). In many cases it is necessary to consider more than one distinct particle type. In the study of gases at moderate temperatures, for example, we may select the molecule as the particle without ignoring the vibration of the atoms within the molecule, or excitation of the electrons; these phenomena are treated as part of the molecular model. As the temperature is increased, we will find that atoms are separated from the molecule (dissociation) and electrons from their atoms (ionization). Since these phenomena divide the molecule into its separate components, we can no longer study these events using the molecule as the particle of our study. We must now choose the separate species, that is, the electrons and the ions, as the distinct particles of our study.

Exercise 1. The resistivity of electrical conductors is a primary consideration in the design of transmission lines. What is a suitable choice of particle(s) to study material resistance to electrical current?

B. Quantum Mechanics

Engineering students are trained in applications of dynamics. Application is primarily to macroscopic objects, whose speeds are much less than that of light and whose total energies are much greater than those of Planckian quanta. Therefore, neither relativistic nor quantum effects need to be included and only the special case of the Newtonian limit is treated, i.e., Classical Mechanics. The thermodynamic properties of systems arise from the dynamic behavior of "very small" particles. The energy of these particles is not, in general, much greater than the Planckian quanta. Therefore, it is usually not possible to implement statistical mechanics to obtain properties without the more accurate methods of

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[1] Indeed, if the detailed individual behavior were known, the amount of data would be so staggering that it could only be sampled statistically.