5.1: Introduction

In this chapter on collisions, we shall have occasion to distinguish between elastic and inelastic collisions. An elastic collision is one in which there is no loss of translational kinetic energy. That is, not only must no translational kinetic energy be degraded into heat, but none of it may be converted to vibrational or rotational kinetic energy. It is well known, for example, that if a ball makes a glancing (i.e. not head-on) elastic collision with another ball of the same mass, initially stationary, then after collision the two balls will move off at right angles to reach other. But this is so only if the balls are smooth. If they are rough, after collision the balls will be spinning, so this result – and any other results that assume no loss of translational kinetic energy − will not be valid. When molecules collide, they may be set into rotational and vibrational motion, and in that case the collision will not be elastic in the sense in which we are using the term. If two atoms collide, one (or both) may be raised to an excited electronic level. Some of the translational kinetic energy has then been converted to potential energy. If the excited atom subsequently drops down to a lower level, that energy is radiated away and lost from the system. Superelastic collisions are also possible. If one atom, before collision, is in an excited electronic state, on collision it may make a radiationless downwards transition, and the potential energy released is then converted to translational kinetic energy, so the collision is superelastic. None of this is intended to mean that elastic collisions are impossible or even rare. In the case of collisions involving macroscopic bodies, such as smooth, hard billiard balls, collisions may not be 100% elastic, but they may be close to it. In the case of low-energy (low temperature) collisions between atoms, there need be no excitation to excited levels, in which case the collision will be elastic. Some subatomic particles, in particular leptons (of which the electron is the best-known example), are believed to have no internal degrees of freedom, and therefore collisions between them are necessarily elastic.

In laying out the principles involved in collisions between particles, we need not suppose that the particles actually "bang into" – i.e. touch – each other. For example most of the principles that we shall be describing apply equally to collisions between balls that "bang into" each other and to phenomena such as Rutherford scattering, in which an alpha particle is deviated from its path by a gold nucleus without actually "touching" it. Of course, if you think about it at an atomic level, when two billiard balls collide, the atoms don't actually "touch" each other; they are repelled from each other by electromagnetic forces, just as the alpha particle and the gold nucleus repelled each other in the Rutherford-Geiger-Marsden experiment.

The theory of collisions is used a great deal, of course, in the study of high-energy collisions between particles in particle physics. Bear in mind, however, that in "atom-smashing" experiments with modern huge particle accelerators, or even in relatively mild collisions such as Compton scattering of x-rays, the particles involved are moving at speeds that are not negligible compared with the speed of light, and therefore relativistic mechanics is needed for a proper analysis. In this chapter, collisions are treated entirely from a nonrelativistic point of view.