Collision (physics)

Contributed by: Paul W. Schmidt

Publication year: 2014

Any interaction between particles, aggregates of particles, or rigid bodies in which they come near enough to exert a mutual influence, generally with exchange of energy. The term collision, as used in physics, does not necessarily imply actual contact.

In classical mechanics, collision problems are concerned with the relation of the magnitudes and direction of the velocities of colliding bodies after collision to the velocity vectors of the bodies before collision. When the only forces on the colliding bodies are those exerted by the bodies themselves, the principle of conservation of momentum states that the total momentum of the system is unchanged in the collision process. This result is particularly useful when the forces between the colliding bodies act only during the instant of collision. The velocities can then change only during the collision process, which takes place in a short time interval. Under these conditions the forces can be treated as impulsive forces, the effects of which can be expressed in terms of an experimental parameter known as the coefficient of restitution, which is discussed later. *See also:* CONSERVATION OF MOMENTUM; IMPACT.

The study of collisions of molecules, atoms, and nuclear particles is an important field of physics. Here the object is usually to obtain information about the forces acting between the particles. The velocities of the particles are measured before and after collision. Although quantum mechanics instead of classical mechanics should be used to describe the motion of the particles, many of the conclusions of classical collision theory are valid. *See also:* SCATTERING EXPERIMENTS (ATOMS AND MOLECULES); SCATTERING EXPERIMENTS (NUCLEI).

Classification

Collisions can be classed as elastic and inelastic. In an elastic collision, mechanical energy is conserved; that is, the total kinetic energy of the system of particles after collision equals the total kinetic energy before collision. For inelastic collisions, however, the total kinetic energy after collision is different from the initial total kinetic energy.

In classical mechanics the total mechanical energy after an inelastic collision is ordinarily less than the initial total mechanical energy, and the mechanical energy which is lost is converted into heat. However, an inelastic collision in which the total energy after collision is greater than the initial total energy sometimes can occur in classical mechanics. For example, a collision can cause an explosion which converts chemical energy into mechanical energy. In molecular, atomic, and nuclear systems, which are governed by quantum mechanics, the energy levels of the particles can be changed during collisions. Thus these inelastic collisions can involve either a gain or loss in mechanical energy.

Consider a one-dimensional collision of two particles in which the particles have masses m_1 and m_2 and initial velocities u_1 and u_2. If they interact only during the collision, an application of the principle of conservation of momentum yields Eq. (1),

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2 \qquad (1)$$

where v_1 and v_2 are the velocities of m_1 and m_2, respectively, after collision.

Coefficient of restitution

It has been found experimentally that in collision processes Eq. (2)

$$e = \frac{v_2 - v_1}{u_1 - u_2} \qquad (2)$$

holds, where e is a constant known as the coefficient of restitution, the value of which depends on the properties of the colliding bodies. The magnitude of e varies from 0 to 1. A coefficient of restitution equal to 1 can be shown to be equivalent to an elastic collision, while a coefficient of restitution of zero is equivalent to what is sometimes called a perfectly inelastic collision. From the definition of e one can show that in a perfectly inelastic collision the colliding bodies stick together after collision, as two colliding balls of putty or a bullet fired into a wooden block would do. Equations (1) and (2) can be solved for the unknown velocities v_2 and v_1 in the one-dimensional collision of two particles.

The concept of coefficient of restitution can be generalized to treat collisions involving the plane motion of smooth bodies—both of particles and larger bodies for which rotation effects must be considered. For these collisions, experiments show that the velocity components to be used in Eq. (2) for e are the components along the common normal to the surfaces of the bodies at the point where they make contact in the collision. For smooth bodies the velocity components perpendicular to this direction are unchanged. Use of this result and the principle of conservation of momentum is sufficient to solve two- dimensional collision problems of smooth bodies. For collisions of smooth spheres the velocity components to be used in Eq. (2) for e are those on the line joining the centers of the spheres. Velocity components perpendicular to this direction are unchanged.

Center-of-mass coordinates

A simplification of the description of both classical and quantum mechanical collisions can be obtained by using a coordinate system which moves with the velocity of the center of mass before collision. (Since for an isolated system the center of mass of the system can be shown to be unaccelerated at all times, the velocity of the center of mass of the system of particles does not change during collision.) The coordinate system which moves with the center of mass is called the center-of-mass system, while the stationary system is the laboratory system.

The description of a collision in the center-of-mass system is simplified because in this coordinate system the total momentum is equal to zero, both before and after collision. In the case of a two-particle collision the particles therefore must be oppositely directed after collision, and the magnitude of one of the velocities in the center-of-mass system can be determined if the other magnitude is known. *See also:* CENTER OF MASS.

Paul W. Schmidt

Bibliography

D. Halliday, R. Resnick, and K. Krane, *Physics*, 5th ed., Wiley, New York, 2002

H. D. Young and R. A. Freedman, *Sears and Zemansky's University Physics*, 13th ed., Addison Wesley, Boston, 2012

Additional Readings

K. Franklin et al., *Introduction to Biological Physics for the Health and Life Sciences*, John Wiley & Sons, Chichester, West Sussex, UK, 2010

E. B. Podgorsak, *Radiation Physics for Medical Physicists*, 2d ed., Springer, New York, 2010

R. Schräpler et al., The physics of protoplanetesimal dust agglomerates. VII. The low-velocity collision behavior of large dust agglomerates, *Astrophys. J.*, 758(1):35, 2012 DOI: http://doi.org/10.1088/0004-637X/758/1/35