7.2 IMPULSE AND CHANGE OF MOMENTUM

Newton's second law says that at each instant the net force on a body is equal to the rate of change of momentum of the body.

$$\vec{F} = \frac{d\vec{p}}{dt}. \tag{7.13}$$

Suppose you push a box on a floor with a net average force $\vec{F}_{ave}$ for a time Δt. Then, the change in momentum will be

$$\Delta\vec{p} = \vec{F}_{ave}\Delta t, \tag{7.14}$$

which means that the change in momentum is actually equal to the average impulse imparted to the body. For a time-varying force, the impulse will be an integral as shown above. If a time varying force acts from time t_1 to t_2, then the approximate equation, Eq. 7.14 must be replaced by the following more complete statement of the change in momentum over the interval.

$$\boxed{\vec{p}(t_2) - \vec{p}(t_1) = \int_{t_1}^{t_2} \vec{F}(t)dt.} \tag{7.15}$$

Example 7.2.1. Change of momentum of a golf ball. A player hits a 46-gram golf ball with an average force of 4, 600 N while the golf club is in contact with the ball for 0.5 msec. Find the speed of the ball immediately after leaving the club if the golf ball was at rest before being it was struck.

Solution. We can find the speed of the ball by first calculating the change in momentum. Now, a change in momentum can be obtained if we know the momentum at the end and at the beginning. But, here, we only know the momentum at the beginning, which is zero. Our discussion in this section says that, according to Newton's second law, you can use impulse to deduce the resulting change in momentum also. For a calculation of the impulse, we need the force and the duration for which the force has acted, both of which are given in the problem. Therefore, the impulse on the ball is given by

$$\begin{aligned} &\text{Magnitude: } J = 4600\text{ N} \times 0.5 \times 10^{-3}\text{ s} = 2.3\text{ N.s.} \\ &\text{Direction: in the direction of the force.} \end{aligned} \tag{7.16}$$

This is equal to the change in momentum of the ball. Dividing by mass we find the velocity at the end of the interval since velocity is zero at the beginning of the interval.

$$\vec{v} = \{50\ m/s, \text{from club towards ball}\}.$$

Therefore, the speed of the ball after the hit will be 50 m/s.