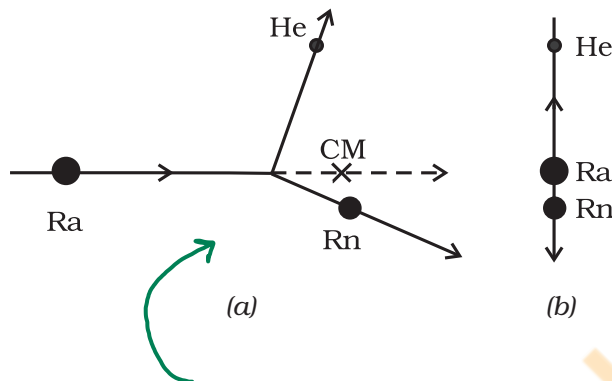


complicated trajectories. Yet, if the total external force acting on the system is zero, the centre of mass moves with a constant velocity, i.e., moves uniformly in a straight line like a free particle.

The vector Eq. (7.18a) is equivalent to three scalar equations,

$$P_x = c_1, P_y = c_2 \text{ and } P_z = c_3 \quad (7.18 \text{ b})$$

Here  $P_x$ ,  $P_y$  and  $P_z$  are the components of the total linear momentum vector  $\mathbf{P}$  along the  $x$ -,  $y$ - and  $z$ -axes respectively;  $c_1$ ,  $c_2$  and  $c_3$  are constants.

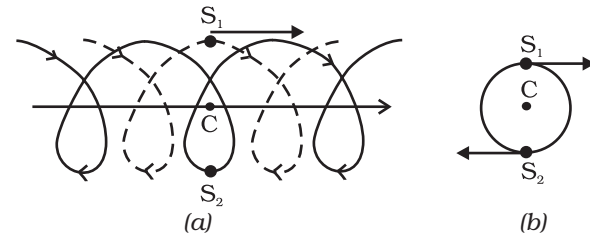


**Fig. 7.13 (a)** A heavy nucleus radium (Ra) splits into a lighter nucleus radon (Rn) and an alpha particle (nucleus of helium atom). The CM of the system is in uniform motion.

**(b)** The same splitting of the heavy nucleus radium (Ra) with the centre of mass at rest. The two product particles fly back to back.

As an example, let us consider the radioactive decay of a moving unstable particle, like the nucleus of radium. A radium nucleus disintegrates into a nucleus of radon and an alpha particle. The forces leading to the decay are internal to the system and the external forces on the system are negligible. So the total linear momentum of the system is the same before and after decay. The two particles produced in the decay, the radon nucleus and the alpha particle, move in different directions in such a way that their centre of mass moves along the same path along which the original decaying radium nucleus was moving [Fig. 7.13(a)].

If we observe the decay from the frame of reference in which the centre of mass is at rest, the motion of the particles involved in the decay looks particularly simple; the product particles



**Fig. 7.14 (a)** Trajectories of two stars,  $S_1$  (dotted line) and  $S_2$  (solid line) forming a binary system with their centre of mass  $C$  in uniform motion.

**(b)** The same binary system, with the centre of mass  $C$  at rest.

move back to back with their centre of mass remaining at rest as shown in Fig. 7.13 (b).

In many problems on the system of particles, as in the above radioactive decay problem, it is convenient to work in the centre of mass frame rather than in the laboratory frame of reference.

*This method is used in advanced level prob.*

In astronomy, binary (double) stars is a common occurrence. If there are no external forces, the centre of mass of a double star moves like a free particle, as shown in Fig. 7.14 (a). The trajectories of the two stars of equal mass are also shown in the figure; they look complicated. If we go to the centre of mass frame, then we find that there the two stars are moving in a circle, about the centre of mass, which is at rest. Note that the position of the stars have to be diametrically opposite to each other [Fig. 7.14(b)]. Thus in our frame of reference, the trajectories of the stars are a combination of (i) uniform motion in a straight line of the centre of mass and (ii) circular orbits of the stars about the centre of mass.

As can be seen from the two examples, **separating** the motion of different parts of a system into motion **of the centre of mass and motion about the centre of mass** is a very useful technique that helps in understanding the motion of the system.

## 7.5 VECTOR PRODUCT OF TWO VECTORS

We are already familiar with vectors and their use in physics. In chapter 6 (Work, Energy, Power) we defined the scalar product of two vectors. An important physical quantity, work, is defined as a scalar product of two vector quantities, force and displacement.