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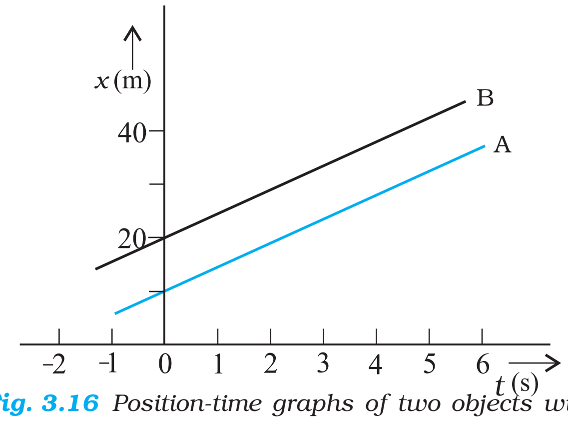

Fig. 3.16 *Position-time graphs of two objects with equal velocities.*

This shows: $$\boxed{v_{BA} = -v_{AB}} \tag{3.14c}$$

Now we consider some special cases :

(a) If $v_B = v_A$, $v_B - v_A = 0$. Then, from Eq. (3.13), $x_B(t) - x_A(t) = x_B(0) - x_A(0)$. Therefore, the two objects stay at a constant distance ($x_B(0) - x_A(0)$) apart, and their position–time graphs are straight lines parallel to each other as shown in Fig. 3.16. The relative velocity v_{AB} or v_{BA} is zero in this case.

(b) If $v_A > v_B$, $v_B - v_A$ is negative. One graph is steeper than the other and they meet at a common point. For example, suppose $v_A = 20$ m s^{-1} and $x_A(0) = 10$ m; and $v_B = 10$ m s^{-1}, $x_B(0) = 40$ m; then the time at which they meet is $t = 3$ s (Fig. 3.17). At this instant they are both at a position $x_A(t) = x_B(t) = 70$ m. Thus, object A overtakes object B at this time. In this case, $v_{BA} = 10$ m s^{-1} – 20 m s^{-1} = – 10 m s^{-1} = $-v_{AB}$.

(c) Suppose v_A and v_B are of opposite signs. For example, if in the above example object A is moving with 20 m s^{-1} starting at $x_A(0) = 10$ m and object B is moving with – 10 m s^{-1} starting at $x_B(0) = 40$ m, the two objects meet at $t = 1$ s (Fig. 3.18). The velocity of B relative to A, v_{BA} = [–10 – (20)] m s^{-1} = –30 m s^{-1} = $-v_{AB}$. In this case, the magnitude of v_{BA} or v_{AB} (= 30 m s^{-1}) is greater than the magnitude of velocity of A or that of B. If the objects under consideration are two trains, then for a person sitting on either of the two, the other train seems to go very fast.

Note that Eq. (3.14) are valid even if v_A and v_B represent instantaneous velocities.

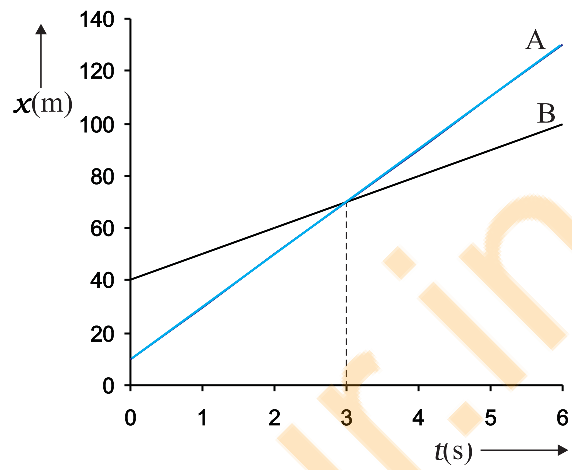

Fig. 3.17 *Position-time graphs of two objects with unequal velocities, showing the time of meeting.*

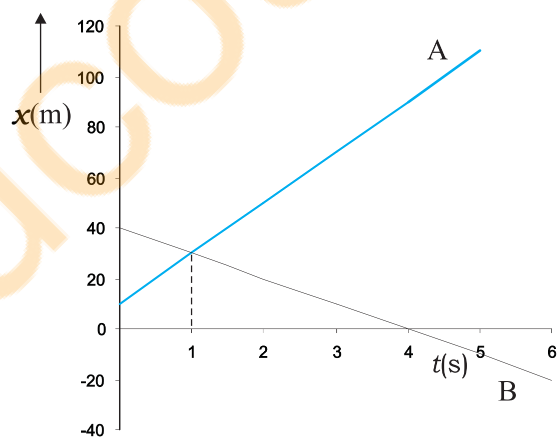

Fig. 3.18 *Position-time graphs of two objects with velocities in opposite directions, showing the time of meeting.*

Example 3.9 Two parallel rail tracks run north-south. Train A moves north with a speed of 54 km h^{-1}, and train B moves south with a speed of 90 km h^{-1}. What is the

(a) velocity of B with respect to A ?,

(b) velocity of ground with respect to B ?, and

(c) velocity of a monkey running on the roof of the train A against its motion (with a velocity of 18 km h^{-1} with respect to the train A) as observed by a man standing on the ground ?

Answer Choose the positive direction of x-axis to be from south to north. Then,

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