PHY 111: Principles of Physics I Summer 2023

LECTURE 08.5 — July 2, 2023

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1 Relative motion

Relative motion refers to the motion of one object with respect to another. In other words, relative motion is the comparison of the motion of one object to that of another.

For example, consider a car moving down the highway. If you are inside the car, you may feel as though you are stationary and the world is moving past you. But if you step outside the car and observe it from a fixed point on the side of the road, you will see the car moving **relative** to you. The same concept applies to two boats moving relative to each other on a lake or two airplanes flying in formation.

Similar to Kinematics, a relative motion has relative displacements, relative velocities, and relative accelerations.

1.1 Relative Displacement

Relative displacement is the change in one object's position relative to another. In other words, it is the distance between the initial and final positions of one object as measured from the position of another object.

It is a vector quantity, meaning it has both magnitude and direction. The magnitude of the relative displacement is the distance between the initial and final positions of one object as measured from the position of another, and the direction of the relative displacement is the direction of the shortest path between the two positions.

Consider the following system where a cyclist observes a passenger moving onboard a bus. Assuming the bus is moving with a **constant** velocity $v_{B/C}$ away from the cyclist. Thus, the cyclist will experience a relative motion between himself and the passenger onboard the bus.

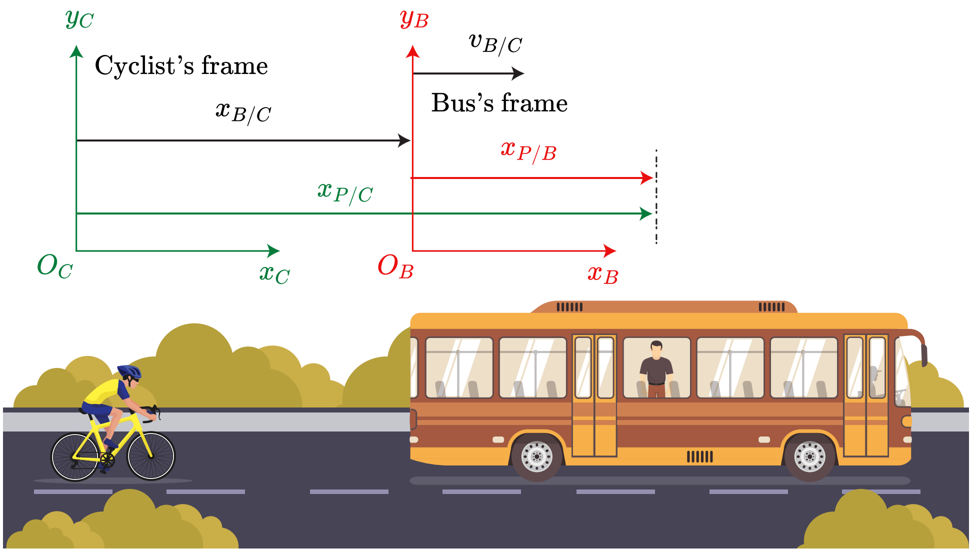

FIGURE 1: Relative motion between an observer and observee. The system is in 1D.

The position of the passenger relative to the cyclist $x_{P/C}$ will be the sum of the position of the passenger relative to the bus $x_{P/B}$, and the velocity of the bus frame relative to the cyclist $x_{B/C}$.

$$x_{P/C} = x_{P/B} + x_{B/C} \tag{1}$$

This apparent sense of displacement causes relative motion.

1.2 Relative Velocity

Relative velocity is the velocity of an object relative to another object. In other words, it is the velocity of one object with respect to another. The concept of relative velocity is essential in kinematics, where the motion of an object can be affected by the motion of other nearby objects.

We consider the same system mentioned above and differentiate (1) with respect to time, giving us the velocity equation for the system.

$$\frac{dx_{P/C}}{dt} = \frac{dx_{P/B}}{dt} + \frac{dx_{B/C}}{dt}$$

$$\therefore v_{P/C} = v_{P/B} + v_{B/C} \tag{2}$$

Relative velocity is a vector quantity that has both magnitude and direction. The magnitude of the relative velocity is equal to the difference in the magnitudes of the velocities of the two objects. In contrast, the direction of the relative velocity is the direction in which the second object moves relative to the first object.

1.3 Relative Acceleration

For the same system, we get the following acceleration equation by differentiating (2) with respect to time:

$$\begin{aligned} \frac{dv_{P/C}}{dt} &= \frac{dv_{P/B}}{dt} + \frac{dv_{B/C}}{dt} \\ \therefore a_{P/C} &= a_{B/C} \end{aligned} \tag{3}$$

Since the bus is moving away from the cyclist with a *constant* velocity, the acceleration between the two systems is zero. Thus, the cyclist will measure the same acceleration in his frame as the one in the bus's frame. This is a case of constant relative acceleration.

TAKEAWAY: Relative acceleration is not always constant. The relative acceleration between two objects depends on the forces acting on them and can change over time.