4.10: Motion Along a Straight Line (Summary)

Key Terms

acceleration due to gravity	acceleration of an object as a result of gravity
average acceleration	the rate of change in velocity; the change in velocity over time
average speed	the total distance traveled divided by elapsed time
average velocity	the displacement divided by the time over which displacement occurs
displacement	the change in position of an object
distance traveled	the total length of the path traveled between two positions
elapsed time	the difference between the ending time and the beginning time
free fall	the state of movement that results from gravitational force only
instantaneous acceleration	acceleration at a specific point in time
instantaneous speed	the absolute value of the instantaneous velocity
instantaneous velocity	the velocity at a specific instant or time point
kinematics	the description of motion through properties such as position, time, velocity, and acceleration
position	the location of an object at a particular time
total displacement	the sum of individual displacements over a given time period
two-body pursuit problem	a kinematics problem in which the unknowns are calculated by solving the kinematic equations simultaneously for two moving objects

Key Equations

Displacement	$$\Delta x = x_f - x_i \tag{4.10.1}$$
Total displacement	$$\Delta x_{Total} = \sum \Delta x_i \tag{4.10.2}$$
Average velocity	$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \tag{4.10.3}$$
Instantaneous velocity	$$v(t) = \frac{dx(t)}{dt} \tag{4.10.4}$$
Average speed	$$\bar{s} = \frac{Total\ distance}{Elapsed\ time} \tag{4.10.5}$$
Instantaneous speed	$$Instantaneous\ speed = \|v(t)\| \tag{4.10.6}$$
Average acceleration	$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - x_0}{t_f - t_0} \tag{4.10.7}$$

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Instantaneous acceleration	$$a(t)=\frac{dv(t)}{dt} \tag{4.10.8}$$
Position from average velocity	$$x=x_0+\bar{v}t \tag{4.10.9}$$
Average velocity	$$\bar{v}=\frac{v_0+v}{2} \tag{4.10.10}$$
Velocity from acceleration	$$v=v_0+at\ (constant\ a) \tag{4.10.11}$$
Position from velocity and acceleration	$$x=x_0+v_0t+\frac{1}{2}at^2\ (constant\ a) \tag{4.10.12}$$
Velocity from distance	$$v^2=v_0^2+2a(x-x_0)\ (constant\ a) \tag{4.10.13}$$
Velocity of free fall	$$v=v_0-gt(positive\ upward) \tag{4.10.14}$$
Height of free fall	$$y=y_0+v_0t-\frac{1}{2}gt^2 \tag{4.10.15}$$
Velocity of free fall from height	$$v^2=v_0^2-2g(y-y_0) \tag{4.10.16}$$
Velocity from acceleration	$$v(t)=\int a(t)dt+C_1 \tag{4.10.17}$$
Position from velocity	$$x(t)=\int v(t)dt+C_2 \tag{4.10.18}$$

Summary

3.1 Position, Displacement, and Average Velocity

- Kinematics is the description of motion without considering its causes. In this chapter, it is limited to motion along a straight line, called one-dimensional motion.
- Displacement is the change in position of an object. The SI unit for displacement is the meter. Displacement has direction as well as magnitude.
- Distance traveled is the total length of the path traveled between two positions.
- Time is measured in terms of change. The time between two position points x_1 and x_2 is $\Delta t = t_2 - t_1$. Elapsed time for an event is $\Delta t = t_f - t_0$, where t_f is the final time and t_0 is the initial time. The initial time is often taken to be zero.
- Average velocity $\bar{v}$ is defined as displacement divided by elapsed time. If x_1, t_1 and x_2, t_2 are two position time points, the average velocity between these points is

$$\bar{v}=\frac{\Delta x}{\Delta t}=\frac{x_2-x_1}{t_2-t_1}. \tag{4.10.19}$$

3.2 Instantaneous Velocity and Speed

- Instantaneous velocity is a continuous function of time and gives the velocity at any point in time during a particle's motion. We can calculate the instantaneous velocity at a specific time by taking the derivative of the position function, which gives us the functional form of instantaneous velocity v(t).
- Instantaneous velocity is a vector and can be negative.
- Instantaneous speed is found by taking the absolute value of instantaneous velocity, and it is always positive.
- Average speed is total distance traveled divided by elapsed time.

- The slope of a position-versus-time graph at a specific time gives instantaneous velocity at that time.

3.3 Average and Instantaneous Acceleration

- Acceleration is the rate at which velocity changes. Acceleration is a vector; it has both a magnitude and direction. The SI unit for acceleration is meters per second squared.
- Acceleration can be caused by a change in the magnitude or the direction of the velocity, or both.
- Instantaneous acceleration a(t) is a continuous function of time and gives the acceleration at any specific time during the motion. It is calculated from the derivative of the velocity function. Instantaneous acceleration is the slope of the velocity-versus-time graph.
- Negative acceleration (sometimes called deceleration) is acceleration in the negative direction in the chosen coordinate system.

3.4 Motion with Constant Acceleration

- When analyzing one-dimensional motion with constant acceleration, identify the known quantities and choose the appropriate equations to solve for the unknowns. Either one or two of the kinematic equations are needed to solve for the unknowns, depending on the known and unknown quantities.
- Two-body pursuit problems always require two equations to be solved simultaneously for the unknowns.

3.5 Free Fall

- An object in free fall experiences constant acceleration if air resistance is negligible.
- On Earth, all free-falling objects have an acceleration g due to gravity, which averages $g = 9.81\ m/s^2$.
- For objects in free fall, the upward direction is normally taken as positive for displacement, velocity, and acceleration.

3.6 Finding Velocity and Displacement from Acceleration

- Integral calculus gives us a more complete formulation of kinematics.
- If acceleration a(t) is known, we can use integral calculus to derive expressions for velocity v(t) and position x(t).
- If acceleration is constant, the integral equations reduce to Equation 3.12 and Equation 3.13 for motion with constant acceleration.

Contributors and Attributions

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