HRK Chapter 2 Summary: Kinematics Basics

To really get physics, you gotta understand **acceleration**, **velocity**, and **displacement**.

- **Acceleration** is the rate of change of velocity:

$$a = \frac{\Delta v}{\Delta t}$$

- **Velocity** is the rate of change of position:

$$v = \frac{\Delta x}{\Delta t}$$

- Position change is denoted as Δx.

There are two main ways to find acceleration and velocity: *average* and *instantaneous*.

- **Average acceleration**:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t}$$

- **Average velocity**:

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t}$$

To get instantaneous values, use calculus. Recall the definition of a derivative:

$$f'(x) = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}$$

The derivative gives the rate of change at a specific point — aka the *instantaneous* rate.

- **Instantaneous velocity** is the derivative of position $x(t)$ with respect to time t:

$$v(t) = \frac{dx}{dt}$$

  For example, $v(5) = x'(5) = \frac{d}{dt}x(t)\big|_{t=5}$

- Conversely, the integral of velocity over time gives position:

$$x(t) = \int v(t)\, dt + x_0$$

Note: Speed is the absolute value of velocity,

$$\text{speed} = \frac{\text{distance}}{\text{time}} = |v|$$

Some questions may use speed instead of velocity.

Common kinematics formulas: (useful to memorize)

$$v_f = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$v_x = v_0 x + a_x t$$

For free-fall problems: acceleration is due to gravity, $a = -g$. If not specified, use $g = 9.8\, m/s^2$ downward.

Tip: If acceleration is *not constant*, you must use integrals or the average formulas:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t}, \quad v_{\text{avg}} = \frac{\Delta x}{\Delta t}$$