**Kinematics Reference Guide**

*The Three Equations of Motion*

# Introduction

Kinematics is the branch of physics that describes the motion of objects without considering the forces that cause the motion. This reference guide covers the three fundamental equations of motion that are essential for solving problems involving constant acceleration.

# The Three Equations of Motion

## First Equation of Motion

**v = u + at**

*Relates velocity, acceleration, and time*

**v** = final velocity (m/s)

**u** = initial velocity (m/s)

**a** = acceleration (m/s²)

**t** = time (s)

This equation is derived from the definition of acceleration and shows how the final velocity of an object depends on its initial velocity, the acceleration, and the time for which the acceleration acts.

## Second Equation of Motion

**s = ut + ½at²**

*Gives displacement in terms of initial velocity, time, and acceleration*

**s** = displacement (m)

**u** = initial velocity (m/s)

**t** = time (s)

**a** = acceleration (m/s²)

This equation is particularly useful when you know the initial conditions and time, and need to find how far the object has traveled.

## Third Equation of Motion

**v² = u² + 2as**

*Relates velocities, acceleration, and displacement (time-independent)*

**v** = final velocity (m/s)

**u** = initial velocity (m/s)

**a** = acceleration (m/s²)

**s** = displacement (m)

This equation is especially useful when time is not known or not needed in the problem. It directly relates the change in kinetic energy to the work done by the constant force.

# Key Concepts

## Displacement vs Distance

* **Displacement:** A vector quantity that refers to the change in position of an object. It has both magnitude and direction.
* **Distance:** A scalar quantity that refers to the total path length traveled by an object, regardless of direction.

## Velocity vs Speed

* **Velocity:** A vector quantity that includes both magnitude and direction of motion.
* **Speed:** A scalar quantity that represents only the magnitude of velocity.

## Acceleration

Acceleration is the rate of change of velocity with respect to time. It can be:

* **Positive:** When the object is speeding up in the positive direction
* **Negative:** When the object is slowing down or speeding up in the negative direction

# Problem-Solving Strategy

1. Identify and list all given values with their units
2. Clearly determine what quantity you need to find
3. Choose the most appropriate kinematic equation
4. Substitute the known values into the equation
5. Solve algebraically and check that units are correct

# Common Problem Types

## Type 1: Finding Final Velocity

**Given:** Initial velocity (u), acceleration (a), time (t)

**Use:** v = u + at

## Type 2: Finding Displacement

**Given:** Initial velocity (u), acceleration (a), time (t)

**Use:** s = ut + ½at²

## Type 3: Time-Independent Problems

**Given:** Initial velocity (u), final velocity (v), acceleration (a)

**Use:** v² = u² + 2as

# Sign Conventions

**Positive direction:** Usually chosen as upward or rightward

**Negative direction:** Usually chosen as downward or leftward

**Gravity:** g = -9.8 m/s² (when upward is taken as positive)

It is crucial to establish and maintain a consistent coordinate system throughout the problem-solving process.

# Worked Example

**Problem:**

A car accelerates from rest at 2 m/s² for 5 seconds. Find the final velocity and displacement.

**Given:**

* u = 0 m/s (from rest)
* a = 2 m/s²
* t = 5 s

**Solution:**

**Step 1 - Find final velocity:**

Using v = u + at

v = 0 + (2)(5) = 10 m/s

**Step 2 - Find displacement:**

Using s = ut + ½at²

s = 0(5) + ½(2)(5)² = 0 + ½(2)(25) = 25 m

**Answer:**

Final velocity = 10 m/s, Displacement = 25 m

# Quick Reference Table

| **Given Variables** | **Use Equation** | **To Find** |
| --- | --- | --- |
| u, a, t | v = u + at | v (final velocity) |
| u, a, t | s = ut + ½at² | s (displacement) |
| u, v, a | v² = u² + 2as | s (displacement) |
| u, v, t | s = (u + v)t/2 | s (displacement) |

# Standard Units

| **Quantity** | **Symbol** | **SI Unit** |
| --- | --- | --- |
| Displacement/Distance | s | meters (m) |
| Velocity/Speed | v, u | meters per second (m/s) |
| Acceleration | a | meters per second squared (m/s²) |
| Time | t | seconds (s) |

# Tips for Success

**Essential Guidelines:**

* Always define your coordinate system before starting
* Verify that acceleration is constant before using these equations
* Pay careful attention to positive and negative signs
* Always check that your final answer has the correct units
* Draw a diagram or sketch the motion when possible
* Double-check your algebra and arithmetic
* Ensure your answer makes physical sense

# Conclusion

Mastering these three equations of motion is fundamental to understanding kinematics. With practice, you'll develop the ability to quickly identify which equation to use for different types of problems. Remember that these equations only apply when acceleration is constant, which is a common assumption in introductory physics problems.

Regular practice with various problem types will help you gain confidence in applying these concepts to real-world situations.