PHYS11 CH:1-3

Foundations of Physics, Motion, and Kinematics

Mr. Gullo

July 23, 2025

Learning Objectives

- Define physics and its role as a fundamental science.
- Differentiate between physical quantities, units, accuracy, and precision.
- Distinguish between scalar quantities (distance, speed) and vector quantities (displacement, velocity).
- Define acceleration as the rate of change of velocity.
- Analyze and interpret motion using position-time and velocity-time graphs.
- Understand the meaning of slope and area in motion graphs.
- Identify and apply the kinematic equations for motion with constant acceleration.

What is Physics?

- Physics is the most fundamental of the sciences, concerning itself with energy, matter, space and time, and their interactions.
- It provides the basis for all other sciences, including chemistry, biology, and geology.
- **Modern Physics** includes two revolutionary theories:
  - **Relativity:** Describes how time, space, and gravity can be different for different observers.
  - **Quantum Mechanics:** Describes the behavior of subatomic particles.

Physical Quantities & Units

- A **physical quantity** is a property of an object that can be measured (e.g., length, mass, time).
- We use the **SI system** (metric system) for consistency.
- The four fundamental units we will use are:
  - Length: **meter (m)**
  - Mass: **kilogram (kg)**
  - Time: **second (s)**
  - Electric Current: **ampere (A)**
- Unit conversions are essential for solving problems correctly.

Accuracy vs. Precision

Accuracy How close a measurement is to the correct or accepted value.

Precision How close repeated measurements are to each other, regardless of their accuracy.

An instrument can be precise without being accurate, or accurate without being precise. Our goal is to be both accurate and precise.

Concept Visualization: Accuracy & Precision

To understand the difference between accuracy and precision, we can use the analogy of a dartboard.

- **Accuracy** is hitting the bullseye.
- **Precision** is having all your darts land close together.

On the next slide, we will see four different scenarios.

Visualizing Accuracy & Precision

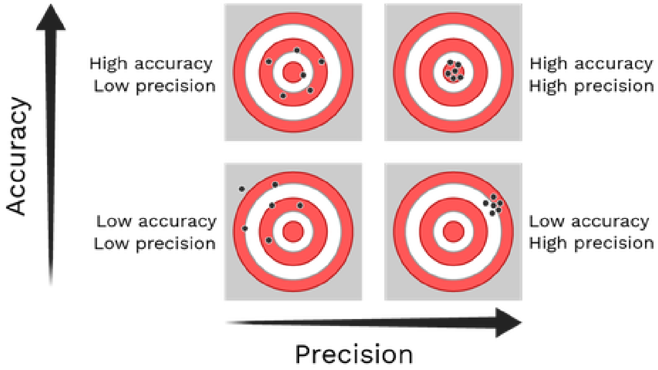


Figure: Four targets showing different combinations of accuracy and precision

Distance vs. Displacement

- **Distance** is a scalar quantity. It is the total length of the path traveled.
  - Example: If you walk 5 meters east and 5 meters west, your distance traveled is 10 m.
- **Displacement** ($\Delta\vec{d}$) is a vector quantity. It is the change in position from the start point to the end point.
  - $\Delta\vec{d} = \vec{d}_{final} - \vec{d}_{initial}$
  - In the example above, your displacement is 0 m because you ended where you started.

Concept Visualization: Distance vs. Displacement

Imagine a person walking from their house to a store. The path they take might involve several turns.

- The **distance** is the full length of the winding path they walked.
- The **displacement** is the straight-line distance and direction from the house to the store.

The next slide shows a map illustrating this.

Visualizing Distance vs. Displacement

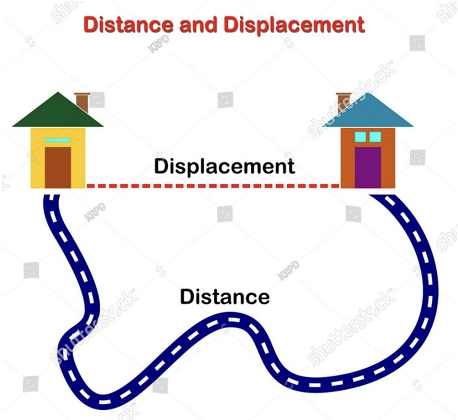


Figure: Map showing winding path (distance) vs. straight-line path (displacement)

Speed vs. Velocity

- **Average Speed** is a scalar quantity that describes the rate of covering distance.
  - $v_{avg} = \frac{\text{distance}}{\text{time}}$
- **Velocity** is a vector quantity that describes the rate of displacement. It includes speed **and direction**.
  - $\vec{v}_{avg} = \frac{\text{displacement}}{\text{time}} = \frac{\Delta \vec{d}}{\Delta t}$
- **Instantaneous velocity** is the velocity at a specific moment in time.

Position vs. Time Graphs

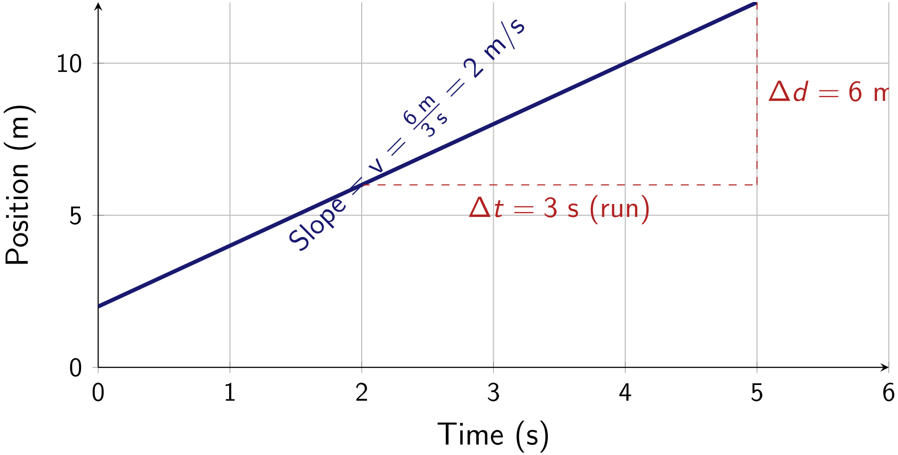
Graphs are a powerful way to visualize and analyze motion.

- On a position-time (p-t) graph, the **y-axis** is position and the **x-axis** is time.
- The slope of the line on a p-t graph represents velocity.
  - Slope $= \frac{\text{rise}}{\text{run}} = \frac{\Delta\text{position}}{\Delta\text{time}} =$ velocity
- A **straight line** means constant velocity.
- A **curved line** means changing velocity (acceleration).

Visualizing Constant Velocity (p-t Graph)

Let's visualize an object moving at a constant, positive velocity. The p-t graph will be a straight line with a positive slope. The value of that slope is the object's velocity.

Position vs. Time Graph (Constant Velocity)



Velocity vs. Time Graphs

We can also graph velocity against time.

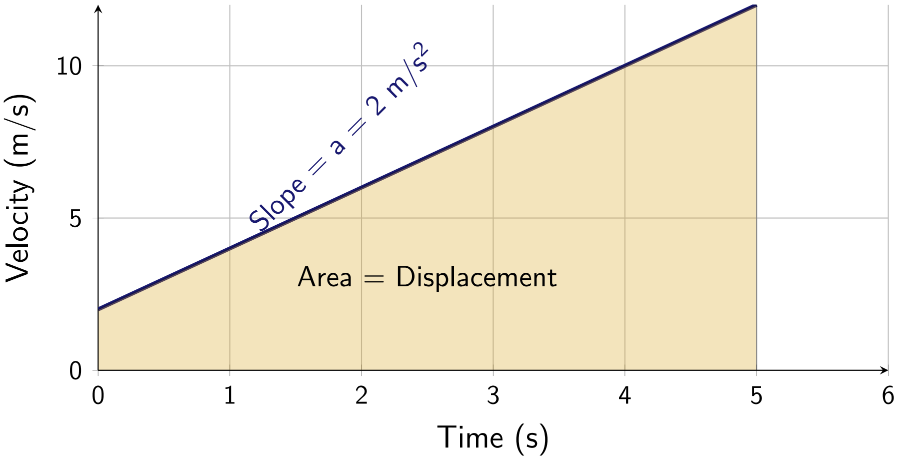
- On a velocity-time (v-t) graph, the **y-axis** is velocity and the **x-axis** is time.
- The slope of the line on a v-t graph represents acceleration.
  - Slope $= \frac{\Delta\text{velocity}}{\Delta\text{time}} =$ acceleration
- The area under the curve of a v-t graph represents displacement.
  - Area $=$ velocity $\times$ time $=$ displacement

Visualizing Constant Acceleration (v-t Graph)

Let's visualize an object moving with constant, positive acceleration. The v-t graph will be a straight line with a positive slope.

- The **slope** of this line is the acceleration.
- The **area** under this line is the total displacement.

Velocity vs. Time Graph (Constant Acceleration)



Acceleration

- **Acceleration** is the rate at which an object's velocity changes. It is a vector quantity.
- It is measured in meters per second squared (m/s^2).
- An object is accelerating if it is:
  - Speeding up
  - Slowing down (this is often called deceleration, but it's still acceleration, just in the opposite direction of velocity)
  - Changing direction
- The formula for average acceleration is:

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_0}{t_f - t_0}$$

Essential Equations: The Kinematics

These equations describe motion with **constant acceleration**.

1. $\vec{v} = \vec{v}_0 + \vec{a}t$
2. $\Delta\vec{d} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$
3. $\vec{v}^2 = \vec{v}_0^2 + 2\vec{a}\Delta\vec{d}$
4. $\Delta\vec{d} = \frac{\vec{v}_0 + \vec{v}}{2}t$

Variables:

$\Delta\vec{d}$: displacement (m)

t: time (s)

$\vec{a}$: acceleration (m/s²)

$\vec{v}_0$: initial velocity (m/s)

$\vec{v}$: final velocity (m/s)

Note: We often write these without vector arrows in 1D problems, using +/- signs for direction.

The GUESS Method

To solve physics problems consistently, we will use the **GUESS** method.

- **G - Givens** List all known quantities from the problem, with variable symbols and units.
- **U - Unknown** Identify the quantity you need to find.
- **E - Equation** Select the physics equation that relates your givens and unknown.
- **S - Substitute** Plug the known values (with units) into the equation.
- **S - Solve** Calculate the result, ensuring correct units and significant figures.

This structured approach helps prevent mistakes and makes your work easy to follow.

I Do: Calculating Average Acceleration I

Problem (12, p. 6)

The driver of a sports car traveling at 10.0 m/s steps down hard on the accelerator for 5.0 s and the velocity increases to 30.0 m/s. What was the average acceleration of the car during the 5.0-s time interval?

I Do: Calculating Average Acceleration II

Solution using GUESS Method

G - Givens:

- Initial velocity (v_i) = 10.0 m/s
- Final velocity (v_f) = 30.0 m/s
- Time interval (t) = 5.0 s

U - Unknown:

- Average acceleration (a) = ?

E - Equation:

$$a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}$$

S - Substitute:

$$a = \frac{30.0\,\mathrm{m/s} - 10.0\,\mathrm{m/s}}{5.0\,\mathrm{s}}$$

S - Solve:

$$a = \frac{20.0\,\mathrm{m/s}}{5.0\,\mathrm{s}}$$

$$a = 4.0\,\mathrm{m/s^2}$$

We Do: Finding Initial Speed I

Problem (8, p. 4)

A motorcycle moving at a constant velocity suddenly accelerates at a rate of 4.0 m/s^2 to a speed of 35 m/s in 5.0 s. What was the initial speed of the motorcycle?

We Do: Finding Initial Speed II

Let's use the GUESS Method

G - Givens:

- Acceleration (a) = 4.0 m/s²
- Final velocity (v_f) = 35 m/s
- Time interval (t) = 5.0 s

U - Unknown:

- Initial velocity (v_i) = ?

E - Equation:

$$v_f = v_i + at$$

How do we rearrange this to solve for v_i?

$$v_i = v_f - at$$

S - Substitute: What values do we substitute into the equation?

$$v_i = 35\,\mathrm{m/s} - (4.0\,\mathrm{m/s^2})(5.0\,\mathrm{s})$$

S - Solve:

You Do: Practice Problem

Problem (24, p. 12)

How long does it take to accelerate from 8.0 m/s to 20.0 m/s at a rate of acceleration of 3.0 m/s^2?

Your Turn

Use the GUESS method to solve the problem.

- Identify your **Givens**.
- State the **Unknown**.
- Select the correct **Equation** and rearrange it.
- **Substitute** the values and **Solve**.

Lesson Summary

- Physics provides the fundamental rules for describing the universe.
- Motion is described using **scalars** (distance, speed) and **vectors** (displacement, velocity, acceleration).
- **Graphs** are a key tool for analyzing motion:
    - The slope of a position-time graph is velocity.
    - The slope of a velocity-time graph is acceleration.
    - The area under a velocity-time graph is displacement.
- For motion with **constant acceleration**, we use the kinematic equations to relate displacement, velocity, acceleration, and time.