PHYS11 CH:1.3

The Language of Physics: Physical Quantities and Units

Mr. Gullo

September 5, 2025

Outline

Learning Objectives

By the end of this section, you will be able to:

Learning Objectives

By the end of this section, you will be able to:

- Associate physical quantities with their International System of Units (SI) and perform conversions among SI units using scientific notation.

Learning Objectives

By the end of this section, you will be able to:

- Associate physical quantities with their International System of Units (SI) and perform conversions among SI units using scientific notation.
- Relate measurement uncertainty to significant figures and apply the rules for using significant figures in calculations.

Learning Objectives

By the end of this section, you will be able to:

- Associate physical quantities with their International System of Units (SI) and perform conversions among SI units using scientific notation.
- Relate measurement uncertainty to significant figures and apply the rules for using significant figures in calculations.
- Correctly create, label, and identify relationships in graphs using mathematical relationships (e.g., slope, y-intercept).

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).
- **Derived Units:** Combinations of base units (e.g., speed in m/s).

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).
- **Derived Units:** Combinations of base units (e.g., speed in m/s).

Scientific Notation

A method for writing very large or small numbers.

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).
- **Derived Units:** Combinations of base units (e.g., speed in m/s).

Scientific Notation

A method for writing very large or small numbers.

- Format: $x \times 10^y$

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).
- **Derived Units:** Combinations of base units (e.g., speed in m/s).

Scientific Notation

A method for writing very large or small numbers.

- Format: $x \times 10^y$
- Example: The number $840,000,000,000,000$ is written as 8.40×10^{14}.

SI Units & Scientific Notation

Physical Quantities and Units

Physics relies on making measurements, which are expressed in terms of **units**.

- **Base Units:** The seven fundamental units of the SI system (meter, kilogram, second, ampere, kelvin, mole, candela).
- **Derived Units:** Combinations of base units (e.g., speed in m/s).

Scientific Notation

A method for writing very large or small numbers.

- Format: $x \times 10^y$
- Example: The number $840,000,000,000,000$ is written as 8.40×10^{14}.
- The power of 10 is called the **order of magnitude**.

Accuracy, Precision, and Uncertainty

Definitions

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

Accuracy, Precision, and Uncertainty

Definitions

- **Accuracy:** How close a measurement is to the correct or accepted value.
- **Precision:** How well repeated measurements generate the same or similar results.

Accuracy, Precision, and Uncertainty

Definitions

- **Accuracy:** How close a measurement is to the correct or accepted value.
- **Precision:** How well repeated measurements generate the same or similar results.
- **Uncertainty:** A "disclaimer" for your measured value, often written as a $\pm$ amount. E.g., 11.0 ± 0.2 inches.

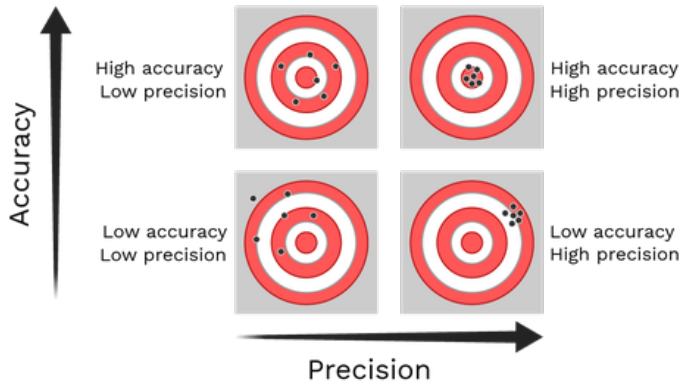


Figure: Four targets showing different combinations of accuracy and precision

Significant Figures

What are they?

The number of significant figures in a measurement indicates the **precision** of the measuring tool. It includes all digits measured reliably plus one estimated digit.

Significant Figures

What are they?

The number of significant figures in a measurement indicates the **precision** of the measuring tool. It includes all digits measured reliably plus one estimated digit.

0.3 decimeters

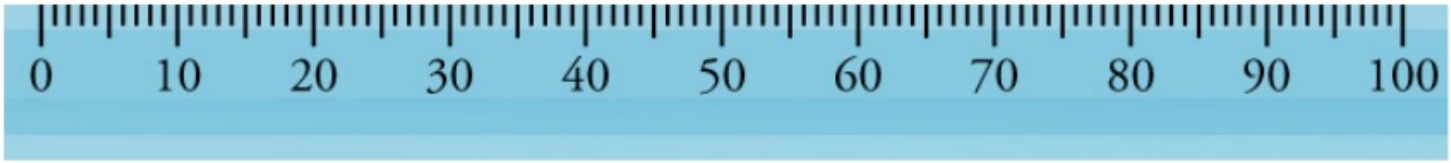
3.6 centimeters

36.5 millimeters

0.3 decimeters

3.6 centimeters

36.5 millimeters



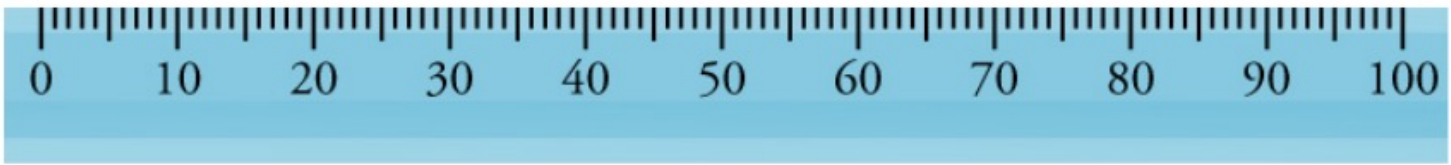
Rules for Zeros

- Zeros between non-zero digits are significant (e.g., 101 has 3 sig figs).

0.3 decimeters

3.6 centimeters

36.5 millimeters



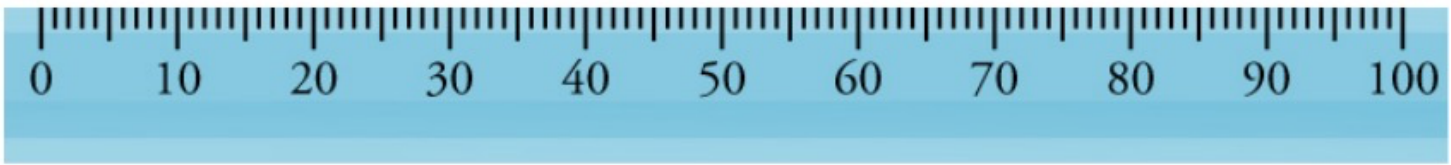
Rules for Zeros

- Zeros between non-zero digits are significant (e.g., 101 has 3 sig figs).
- Leading zeros are not significant (e.g., 0.053 has 2 sig figs).

0.3 decimeters

3.6 centimeters

36.5 millimeters



Rules for Zeros

- Zeros between non-zero digits are significant (e.g., 101 has 3 sig figs).
- Leading zeros are not significant (e.g., 0.053 has 2 sig figs).
- Trailing zeros are ambiguous. Use scientific notation to clarify (e.g., 1.30×10^3 has 3 sig figs, while 1.3×10^3 has 2).

Key Equations & Calculation Rules

Percent Uncertainty

One method of expressing uncertainty is as a percent of the measured value.

Key Equations & Calculation Rules

Percent Uncertainty

One method of expressing uncertainty is as a percent of the measured value.

$$\% \text{ uncertainty} = \frac{\delta A}{A} \times 100\%$$

Key Equations & Calculation Rules

Percent Uncertainty

One method of expressing uncertainty is as a percent of the measured value.

$$\% \text{ uncertainty} = \frac{\delta A}{A} \times 100\%$$

Where A is the measurement and δA is the uncertainty in the measurement.

Key Equations & Calculation Rules

Percent Uncertainty

One method of expressing uncertainty is as a percent of the measured value.

$$\% \text{ uncertainty} = \frac{\delta A}{A} \times 100\%$$

Where A is the measurement and δA is the uncertainty in the measurement.

Rules for Significant Figures in Calculations

- **Multiplication and Division:** The answer should have the same number of significant figures as the starting value with the *fewest* significant figures.

Key Equations & Calculation Rules

Percent Uncertainty

One method of expressing uncertainty is as a percent of the measured value.

$$\% \text{ uncertainty} = \frac{\delta A}{A} \times 100\%$$

Where A is the measurement and δA is the uncertainty in the measurement.

Rules for Significant Figures in Calculations

- **Multiplication and Division:** The answer should have the same number of significant figures as the starting value with the *fewest* significant figures.
- **Addition and Subtraction:** The answer should have the same number of decimal places as the starting value with the *fewest* decimal places.

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

Solution (a): km/h

Average speed $= \frac{10.0\,\text{km}}{20.0\,\text{min}}$. We need to convert minutes to hours.

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

Solution (a): km/h

Average speed $= \frac{10.0\,\text{km}}{20.0\,\text{min}}$. We need to convert minutes to hours.

$$\text{speed} = \frac{10.0\,\text{km}}{20.0\,\text{min}} \times \left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 30.0\,\text{km/h}$$

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

Solution (a): km/h

Average speed $= \frac{10.0\,\text{km}}{20.0\,\text{min}}$. We need to convert minutes to hours.

$$\text{speed} = \frac{10.0\,\text{km}}{20.0\,\text{min}} \times \left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 30.0\,\text{km/h}$$

Solution (b): m/s

We can convert the result from part (a).

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

Solution (a): km/h

Average speed $= \frac{10.0\,\text{km}}{20.0\,\text{min}}$. We need to convert minutes to hours.

$$\text{speed} = \frac{10.0\,\text{km}}{20.0\,\text{min}} \times \left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 30.0\,\text{km/h}$$

Solution (b): m/s

We can convert the result from part (a).

$$\text{speed} = \frac{30.0\,\text{km}}{1\,\text{h}} \times \left(\frac{1000\,\text{m}}{1\,\text{km}}\right) \times \left(\frac{1\,\text{h}}{3600\,\text{s}}\right) = 8.33\,\text{m/s}$$

I Do: Unit Conversion

Problem: A Short Drive Home

Suppose you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed in (a) kilometers per hour (km/h) and (b) meters per second (m/s).

Solution (a): km/h

Average speed $= \frac{10.0\,\text{km}}{20.0\,\text{min}}$. We need to convert minutes to hours.

$$\text{speed} = \frac{10.0\,\text{km}}{20.0\,\text{min}} \times \left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 30.0\,\text{km/h}$$

Solution (b): m/s

We can convert the result from part (a).

$$\text{speed} = \frac{30.0\,\text{km}}{1\,\text{h}} \times \left(\frac{1000\,\text{m}}{1\,\text{km}}\right) \times \left(\frac{1\,\text{h}}{3600\,\text{s}}\right) = 8.33\,\text{m/s}$$

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

Setup

1. Identify the given values:
   - Mass (A) = 65 kg
   - Percent Uncertainty = 3 %

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

Setup

1. Identify the given values:
   - Mass (A) = 65 kg
   - Percent Uncertainty = 3 %
2. Start with the formula: % uncertainty = $\frac{\delta A}{A} \times 100\%$

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

Setup

1. Identify the given values:
   - Mass (A) = 65 kg
   - Percent Uncertainty = 3 %
2. Start with the formula: % uncertainty $= \frac{\delta A}{A} \times 100\%$
3. Rearrange to solve for the uncertainty, δA:

$$\delta A = \frac{\%\text{ uncertainty}}{100\%} \times A$$

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

Setup

1. Identify the given values:
   - Mass (A) = 65 kg
   - Percent Uncertainty = 3 %
2. Start with the formula: % uncertainty $= \frac{\delta A}{A} \times 100\%$
3. Rearrange to solve for the uncertainty, δA:

$$\delta A = \frac{\%\text{ uncertainty}}{100\%} \times A$$

Let's Solve It!

Now, plug in the numbers. What do you get for the uncertainty δA?

We Do: Calculating Uncertainty

Problem

A bathroom scale reads a person's mass as 65 kg with a 3 % uncertainty. What is the uncertainty in their mass in kilograms? (Question 48)

Setup

1. Identify the given values:
   - Mass (A) = 65 kg
   - Percent Uncertainty = 3 %
2. Start with the formula: % uncertainty $= \frac{\delta A}{A} \times 100\%$
3. Rearrange to solve for the uncertainty, δA:

$$\delta A = \frac{\%\text{ uncertainty}}{100\%} \times A$$

Let's Solve It!

Now, plug in the numbers. What do you get for the uncertainty δA?

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers

b. 2.0 megameters

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers

b. 2.0 megameters

c. 2.0 millimeters

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers
b. 2.0 megameters
c. 2.0 millimeters
d. 2.0 micrometers

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers
b. 2.0 megameters
c. 2.0 millimeters
d. 2.0 micrometers

Hint

What metric prefix corresponds to the factor 10^{-3}?

You Do: Metric Prefixes

Problem

Which of the following would describe a length that is 2.0×10^{-3} of a meter? (Question 47)

a. 2.0 kilometers
b. 2.0 megameters
c. 2.0 millimeters
d. 2.0 micrometers

Hint

What metric prefix corresponds to the factor 10^{-3}?

The correct answer is **c.** 2.0 millimeters. The prefix "milli-" means 10^{-3}.

Significant Figures in Mixed Operations

When You Have Both Multiplication and Addition

Key Strategy: Follow the order of operations, keeping track of significant figures at each step.

Significant Figures in Mixed Operations

When You Have Both Multiplication and Addition

Key Strategy: Follow the order of operations, keeping track of significant figures at each step.

Example Problem: Calculate $a \times b + c$

Given: $a = 2.5$, $b = 3.42$, $c = 0.876$

Significant Figures in Mixed Operations

When You Have Both Multiplication and Addition

Key Strategy: Follow the order of operations, keeping track of significant figures at each step.

Example Problem: Calculate $a \times b + c$

Given: $a = 2.5$, $b = 3.42$, $c = 0.876$

Step-by-Step Approach

1. **First:** Perform multiplication $a \times b = 2.5 \times 3.42$
   - 2.5 has 2 sig figs, 3.42 has 3 sig figs
   - Result: $8.55 \rightarrow$ Round to **2 sig figs** $=$ **8.6**

Significant Figures in Mixed Operations

When You Have Both Multiplication and Addition

Key Strategy: Follow the order of operations, keeping track of significant figures at each step.

Example Problem: Calculate $a \times b + c$

Given: $a = 2.5$, $b = 3.42$, $c = 0.876$

Step-by-Step Approach

1. **First:** Perform multiplication $a \times b = 2.5 \times 3.42$
   - 2.5 has 2 sig figs, 3.42 has 3 sig figs
   - Result: $8.55 \rightarrow$ Round to **2 sig figs** $=$ **8.6**
2. **Second:** Perform addition $8.6 + 0.876$
   - 8.6 has 1 decimal place, 0.876 has 3 decimal places
   - Result: $9.476 \rightarrow$ Round to **1 decimal place** $=$ **9.5**

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).
- **Accuracy** is about correctness, while **precision** is about consistency.

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).
- **Accuracy** is about correctness, while **precision** is about consistency.
- **Significant figures** communicate the precision of our measurements and must be handled correctly in calculations.

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).
- **Accuracy** is about correctness, while **precision** is about consistency.
- **Significant figures** communicate the precision of our measurements and must be handled correctly in calculations.
  - Multiplication/Division: Fewest total sig figs.

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).
- **Accuracy** is about correctness, while **precision** is about consistency.
- **Significant figures** communicate the precision of our measurements and must be handled correctly in calculations.
  - Multiplication/Division: Fewest total sig figs.
  - Addition/Subtraction: Fewest decimal places.

Summary

- Physics is a quantitative science, requiring a standard system of units (SI units).
- **Accuracy** is about correctness, while **precision** is about consistency.
- **Significant figures** communicate the precision of our measurements and must be handled correctly in calculations.
  - Multiplication/Division: Fewest total sig figs.
  - Addition/Subtraction: Fewest decimal places.
- **Unit conversion** is a fundamental skill used to ensure calculations are performed with consistent units.