

COURSE CODE: PHY 107

COURSE TITLE: General Practical Physics I

COURSE UNITS: 1 Unit

MODULE 1

Lesson 1: Introduction to Quantitative Measurements

Introduction

Physical measurements are fundamental to experimental physics. They allow us to quantify physical quantities like length, mass, time, and temperature, enabling us to describe and understand the physical world. This lesson introduces the concept of measurement, distinguishes between qualitative and quantitative measurements, emphasizes the importance of standardization and comparison, and explores the concepts of accuracy and precision. We will also discuss SI units, derived units, measurement scales, and common measuring instruments.

Lesson Outcomes: By the end of this lesson, students will be able to:

- Distinguish between qualitative and quantitative measurements.
- Explain the importance of standardization and comparison in physical measurements.
- Define and differentiate between accuracy and precision.
- Identify and use SI units and derived units.
- Describe the function and use of common measuring instruments.
- Perform basic unit conversions and measurements.

Overview of Physical Measurements:

Physical measurements are essential for describing and quantifying physical phenomena. They provide a way to objectively represent the properties of objects and systems. Measurements can be categorized as:

- **Qualitative:** Descriptive observations without numerical values (e.g., "The object is heavy," "The liquid is hot").



- **Quantitative:** Numerical representations of physical quantities (e.g., "The object weighs 50 kg," "The temperature is 30°C").

Quantitative measurements are crucial for scientific progress as they allow for precise comparisons, standardized data collection, and the development of mathematical relationships between physical quantities.

Importance of Measurements:

Measurements play a vital role in scientific investigations:

- **Standardization:** Measurements establish a common language for describing physical quantities, allowing scientists worldwide to communicate effectively and compare results.
- **Comparison:** Quantitative measurements enable direct comparison of data obtained from different experiments or locations, facilitating the identification of patterns and trends.
- **Accuracy and Precision:** Measurements, when performed carefully, improve the accuracy of scientific observations, leading to more reliable and valid conclusions.

Accuracy vs. Precision:

It's crucial to distinguish between accuracy and precision:

- **Accuracy:** How close a measured value is to the true or accepted value of the quantity.
- **Precision:** How close repeated measurements are to each other, regardless of their proximity to the true value.

A measurement can be precise but inaccurate (consistent readings far from the true value), accurate but imprecise (readings scattered around the true value), or ideally, both accurate and precise.

Units and Scales:

SI Units (International System of Units):



The SI system provides a standardized set of units for scientific measurements. Some fundamental SI units include:

- **Length:** meter (m)
- **Mass:** kilogram (kg)
- **Time:** second (s)
- **Temperature:** Kelvin (K)

Derived Units:

Derived units are combinations of fundamental SI units. Examples:

- **Speed:** meters per second (m/s)
- **Force:** newton (N) = $\text{kg} \cdot \text{m/s}^2$
- **Energy:** Joule (J) = $\text{kg} \cdot \text{m}^2/\text{s}^2$

Unit Conversion:

Converting between units is essential for consistency in calculations. Example: Convert 5 kilometers to meters:

$$5 \text{ km} = 5 \times 1000 \text{ m} = 5000 \text{ m}$$

Scales in Measurement:

- **Linear Scales:** Uniform divisions (e.g., a ruler).
- **Digital Scales:** Display readings directly (e.g., digital thermometer, digital balance).

Table of Common Physical Quantities, SI Units, and Measuring Tools:

Quantity	SI Unit	Common Measuring Tools
Length	Meter (m)	Ruler, tape measure, Vernier caliper
Mass	Kilogram (kg)	Balance, digital scale
Time	Second (s)	Stopwatch, atomic clock



Temperature	Kelvin (K)	Thermometer, thermocouple
Electric Current	Ampere (A)	Ammeter
Amount of Substance	Mole (mol)	Balance, chemical analysis techniques

Measuring Instruments:

Common Instruments and Their Uses:

1. **Ruler:** Measures length to the nearest millimeter (or finer, depending on the ruler).
Align the object with the zero mark and read the measurement at the other edge.

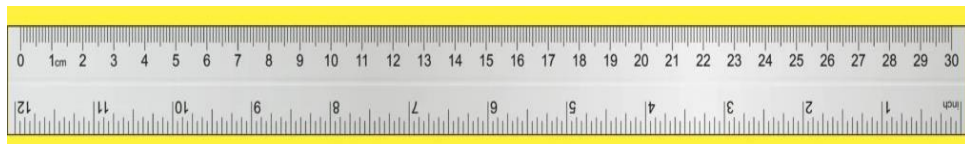


Figure 1: Ruler (<https://myruler.co.uk/>)

2. **Vernier Caliper:** Measures internal and external dimensions and depths with higher precision than a ruler. Uses a vernier scale to interpolate between the smallest divisions on the main scale.

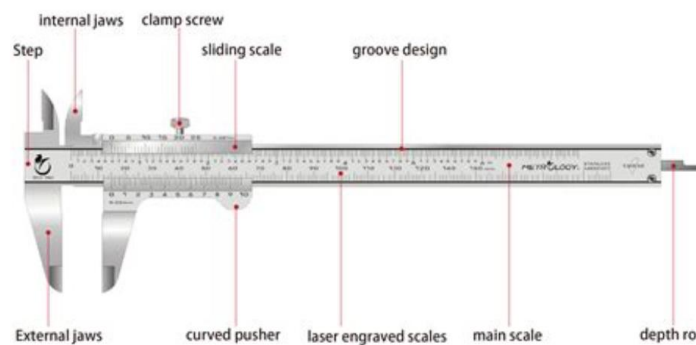


Figure 2: Vernier caliper (<https://galvinconanstuart.blogspot.com/2016/06/vernier-caliper-diagram.html>)

3. **Micrometer Screw Gauge:** Provides even higher precision measurements of small thicknesses, diameters, and lengths.

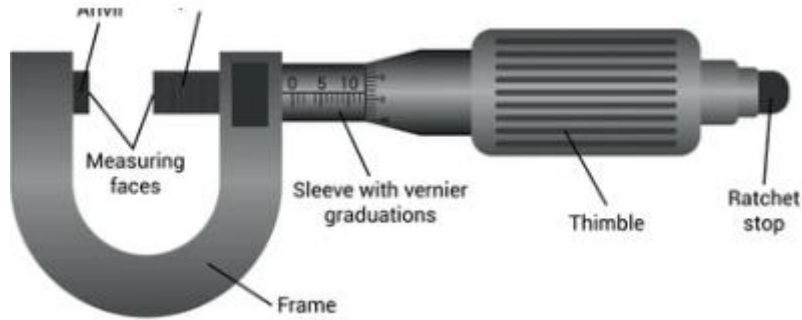


Figure 3: Micrometer Screw-gauge

(<https://www.shutterstock.com/search/micrometer-screw-gauge>)

4. **Oscilloscope:** Measures and visualizes voltage signals as a function of time. Used to analyze waveforms, frequencies, and amplitudes.

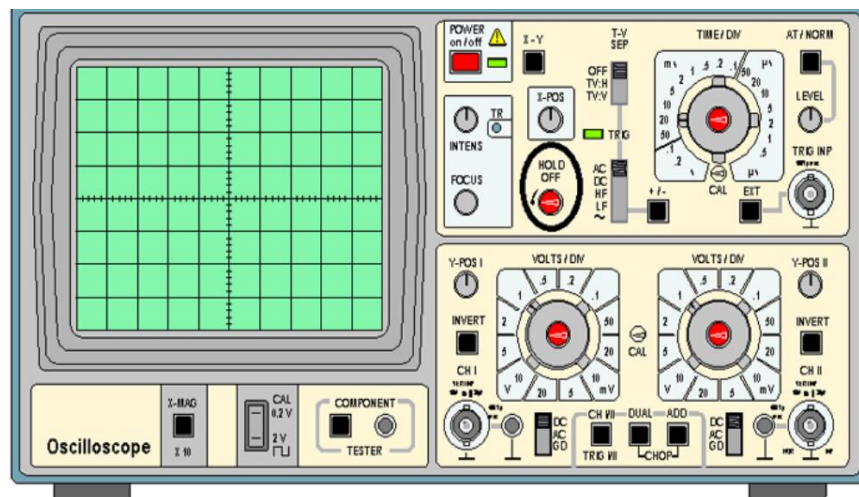


Figure 4: Oscilloscope (<https://www.engineersgarage.com/cro-tutorial-2-working-with-a-cathode-ray-oscilloscope/>)

5. **Multimeter:** Measures voltage, current, and resistance in electrical circuits.



Figure 5: Multimeter

Example Activity: Measuring the Diameter of a Coin:

1. Align the coin along the ruler.
2. Note the reading where the edge of the coin aligns.
3. Record the diameter (e.g., 2.3 cm). Estimate the uncertainty in the measurement.

Summary

Physical measurements are fundamental to experimental physics, and quantitative measurements are essential for scientific progress. Accuracy refers to how close a measurement is to the true value, while precision describes the repeatability of measurements.¹ SI units provide a standardized system of measurement, and unit conversions are crucial for consistency in calculations. Various instruments, each with different levels of precision, are used to measure different physical quantities, and selecting the appropriate instrument is critical for obtaining reliable data.

Evaluation Questions:

1. Explain the difference between qualitative and quantitative measurements, and provide examples of each in a physics context.
2. Discuss the importance of standardization and comparison in physical measurements, and how they contribute to scientific progress.

3. Define and differentiate between accuracy and precision, and provide examples of scenarios where a measurement can be (a) accurate but imprecise, and (b) precise but inaccurate.
4. List the fundamental SI units and provide examples of derived units, explaining how they are formed.
5. Describe the function and use of Vernier calipers and oscilloscopes, and explain their significance in experimental physics.
6. Convert 15 kilometers per hour (km/h) to meters per second (m/s), and explain the steps involved in the conversion.

Suggested Answers:

1. Qualitative vs. Quantitative Measurements:

- Qualitative: Descriptive, non-numerical (e.g., "The wire is hot," "The sound is loud").
- Quantitative: Numerical, measurable (e.g., "The wire's temperature is 80°C," "The sound intensity is 60 dB").

2. Standardization and Comparison:

- Standardization: Provides a common language, ensures consistency, allows for reproducibility.
- Comparison: Enables analysis of data from different experiments, identifies trends, validates theories.
- They are essential for scientific progress because they provide a universal way to share, and verify data.

3. Accuracy vs. Precision:

- Accuracy: Closeness to the true value.
- Precision: Closeness of repeated measurements.
- (a) Accurate but imprecise: Multiple readings scattered around the true value (e.g., a dartboard with darts scattered around the bullseye).
- (b) Precise but inaccurate: Multiple readings clustered far from the true value (e.g., a dartboard with darts tightly clustered off to one side).

4. SI Units and Derived Units:

- Fundamental SI units: meter (m), kilogram (kg), second (s), Kelvin (K), ampere (A), mole (mol), candela (cd).



- Derived units: combinations of fundamental units (e.g., force (N) = $\text{kg}\cdot\text{m}/\text{s}^2$, energy (J) = $\text{kg}\cdot\text{m}^2/\text{s}^2$).

5. Vernier Calipers and Oscilloscopes:

- Vernier calipers: Measure lengths with high precision, using a vernier scale to interpolate between divisions.
- Oscilloscopes: Visualize voltage signals over time, analyze waveforms, measure frequencies and amplitudes.
- Vernier calipers are used for accurate measurements of small distances, and oscilloscopes are used for understanding and analyzing electrical signals.

6. Unit Conversion (15 km/h to m/s):

- $1 \text{ km} = 1000 \text{ m}$, $1 \text{ h} = 3600 \text{ s}$.
- $15 \text{ km/h} = 15 \times (1000 \text{ m} / 3600 \text{ s}) = 15 \times (10/36) \text{ m/s} = 15 \times (5/18) \text{ m/s} = 75/18 \text{ m/s} = 4.17 \text{ m/s}$ (approximately).
- The conversion involves multiplying by the appropriate conversion factors to change the units from kilometers to meters and from hours to seconds.

