Unit 1: Physical Quantities and Measurements

Long Questions

Q.1. Define Science.

Ans. *The field of observation and experimentation to understand the world around us is known as science.* Everything in our lives is closely linked to science and the discoveries made by scientists.

Q.2. Explain the difference between physical and non-physical quantities. Give examples.

Ans.

Physical Quantities	Non-Physical Quantities
Physical quantities can be measured directly or indirectly using tools and instruments.	Non-physical quantities cannot be measured using tools and instruments.
They are measurable and can be expressed in numerical terms.	They are abstract concepts and cannot be quantified.
Examples length, time, temperature, volume, density, etc.	**Examples** love, affection, fear, wisdom, beauty, etc.

Q.3. What is the difference between base quantities and derived quantities? Give examples of each.

Ans.

Base Quantities	Derived Quantities
Base quantities are fundamental physical quantities arbitrary selected by scientist to play a key role in measurements. They provide base for new quantities.	Derived quantities are those that can be described in terms of one or more base quantities.
Examples: Length, mass, time, temperature, electric current, amount of substance and intensity of light.	**Example:** Speed is a derived quantity that depends on distance and time, which are base quantities.

Q.4. What is meant by measurement? Explain.

Ans.*A* ***measurement*** *is a process of comparison of an unknown quantity with widely accepted standard quantity.* A measurement consists of two parts, a number and a unit. A measurement without unit is meaningless.

Challenges of Early Measurement Methods

In the early days, people used their hands, arms, feet, or steps to measure lengths. However, these methods were problematic because the size of hands, arms, and steps varied from person to person, leading to inconsistencies in measurements. This lack of uniformity created confusion when measurements needed to be compared or shared.

Need for Standardization in Measurements

To avoid confusion caused by personal differences, a standard unit of measurement was required. A standard ensures that any person performing a measurement would arrive at the same result. This idea of uniformity is crucial for accuracy and reliability in various fields, such as science, trade, and construction.

Q.5. What is the International System of Units (SI)? Explain.

Ans: i. International System of Units (SI):

Definition: *The International Committee on Weights and Measures in 1961 recommended the use of a system consisting of seven base units known as the* ***International System of Units (SI)***. This system is in use all over the world. The use of SI measurements helps all scientists to share and compare their observations and results easily. The seven base units are fixed with reference to international standards, ensuring consistency and universal understanding across different scientific fields.

ii. Base Units and Derived Units:

Base units cannot be derived from one another and cannot be resolved into anything more basic. However, the units of **derived quantities** such as speed, area, volume, force, pressure, and electric charge can be derived using the base units. These units are called **derived units**. For example:

- **Area** is derived as: Length × Breadth = meter × meter = square meter = m^2
- **Speed** is derived as: Distance / Time = meter / second = m/s

Thus, derived units can be expressed in terms of the base units, enabling scientists to measure a wide range of physical quantities.

Q.6. What are prefixes? What is their use in measurements?

Ans: The SI system is a decimal system, and **prefixes** are used to modify units by powers of 10. Writing large quantities, like 50,000,000 m, or small quantities, like 0.00004 m, is not convenient. Instead, prefixes make these quantities easier to express. For example:

- The quantity **50,000,000 m** can be written as 5×10^7 m **OR** $(50 \times 10^6 m \Rightarrow 50Mm$
- The quantity **0.00004 m** can be written as 4×10^{-5} m **OR**

$(0.04 \times 10^3 m \Rightarrow 0.04Km. (Mega = M = 10^6 : Kilo = K = 10^3)$

Prefixes are the words or symbols added before S.I units such as **milli, centi, kilo, mega, and giga** are used to express quantities in a more manageable form. For example:

- One thousandth (1/1000) of a metre is a **millimetre (mm)**, useful for small measurements like the thickness of a thin wire.
- One thousand metres is a **kilometre (km)**, which is used to measure long distances.

These prefixes simplify the expression of both large and small quantities, making the system more practical and accessible for everyday use.

Q.7. What is scientific notation? Explain.

Ans: Scientific Notation

Definition: Scientific notation is a short way of representing very large or very small numbers. Writing such numbers otherwise takes up much space, making them difficult to read and compare. It also becomes hard to visualize their relative sizes and use them in calculations. These numbers are more conveniently expressed as powers of 10.

Simplification of Numbers

In scientific notation, the numerical part of the quantity is written as a number from 1 to 9, multiplied by whole number powers of 10. This simplification helps avoid writing long strings of numbers and makes calculations easier to perform.

Writing Numbers in Scientific Notation

To write numbers using scientific notation, you move the decimal point until only one non-zero digit remains on the left. Then, you count the number of places the decimal point is moved. This count becomes the power or exponent of 10. If the decimal is moved to the left, the exponent is positive. If it is moved to the right, the exponent is negative.

Examples of Scientific Notation

- The average distance from the Sun to the Earth is 138,000,000 km. In scientific notation, this distance would be written as **1.38×10^8 km**. The decimal point is moved 8 places to the left, so the exponent is positive.
- The diameter of a hydrogen atom is about 0.000000000052 m. In scientific notation, this would be written as **5.2×10^{-11} m**. The decimal point is moved 11 places to the right, so the exponent is negative.

Thus, scientific notation is a helpful tool for expressing very large or very small numbers in a more compact and manageable form.

Q.8. Write a note on meter rule.

Ans: Measuring Length with a Meter Rule:

Length is generally measured using a **meter rule** in the laboratory. The smallest division on a meter scale is **1 mm**, and the smallest measurement that can be taken with a meter rule is **1 mm**. This is known as the **least count** of the meter rule. The least count refers to the smallest measurement that can be accurately taken with an instrument.

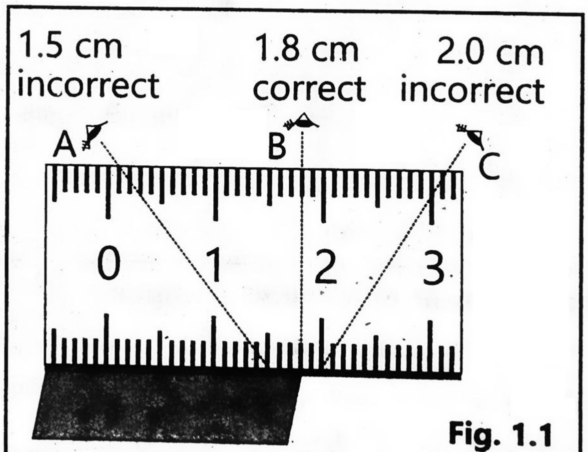

Fig. 1.1

Procedure for Measuring Length

To measure the length of an object, the meter rule is placed in such a way that its zero coincides with one edge of the object. Then, the reading in front of the other edge gives the **length of the object**.

Parallax Error

One common source of error when using a meter rule is the angle at which the instrument is read. The meter rule should either be tipped on its edge or read when the person's eye is directly above the ruler. If the meter rule is read from different angle, the object will appear to be of different lengths. This is known as **parallax error**, which occurs due to the distortion caused by the observer's perspective. This leads to inaccurate measurements and should be avoided to ensure precision.

Q.9. Describe construction and working of Vernier calipers in detail.

Ans: Vernier Caliper

*A **Vernier Caliper** is an instrument used to measure small lengths with high precision, down to **1/10th of a millimeter**.* It is commonly used to measure the thickness, diameter, width, or depth of an object.

Construction:

The Vernier Caliper has two scales:

(a) **Main Scale**: This scale has markings of **1 mm** each.

(b) **Vernier (sliding) Scale**: The Vernier scale is **9 mm** long and divided into **10 equal parts**.

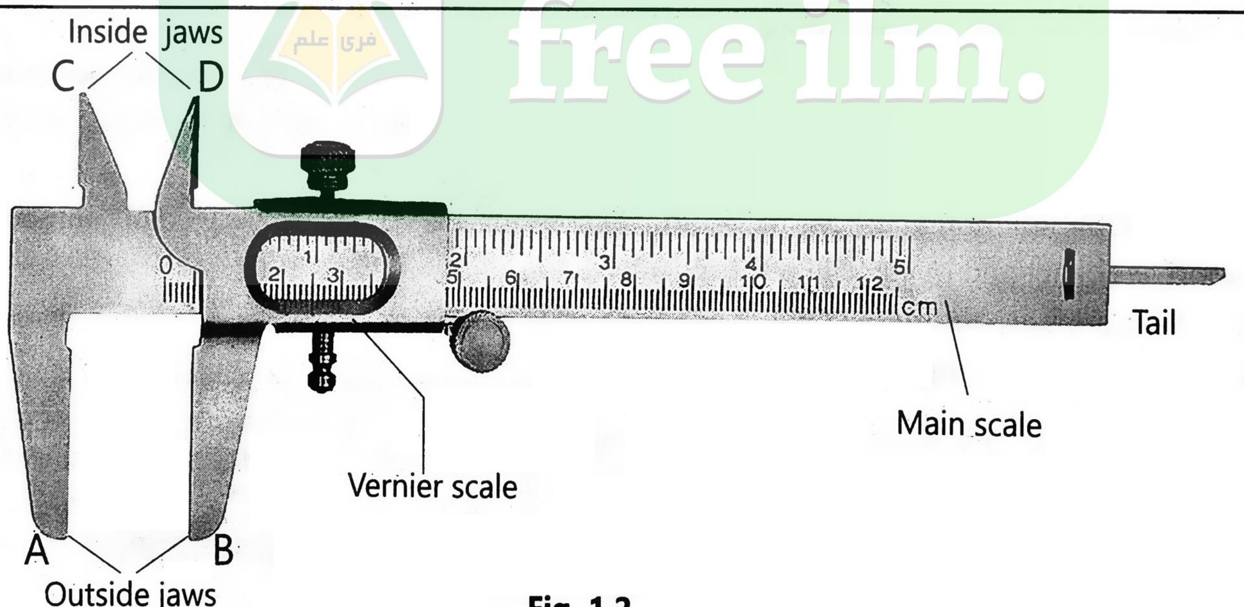

Fig. 1.2

Least Count of Vernier Caliper

The **least count** of a Vernier Caliper is the difference between the value of one main scale division (M.S) and one Vernier scale division (V.S).

Least count = 1 M.S div - 1 V.S div

Least count = 1 mm - 0.9 mm = 0.1 mm

Alternatively, the least count can also be determined by dividing the length of one small division on the main scale by the total number of divisions on the Vernier scale:

Least count = 1 mm / 10 = 0.1 mm.

Jaws and Depth Gauge

The Vernier Caliper also has **two jaws** (A and B) to measure the **external dimensions** of an object. Jaws C and D are used to measure the **internal dimensions** of an object. Additionally, a narrow strip projecting from behind the main scale, known as the **tail or depth gauge**, is used to measure the **depths** of hollow objects.

Working:

Measurement Using Vernier Calipers

Suppose, an object is placed between the two jaws, the position of the Vernier scale on the main scale is shown in the Fig (1.2(a)).

i. Read the main scale marking just infront of zero of the Vernier scale. It [illegible]s 4.3 cm.

ii. Find the Vernier scale marking or division which is in line with any o[illegible] main scale marking. This shows:

$$\text{length of object} = \text{Main scale reading} + (\text{Least count} \times \text{Vernier scale reading}).$$
$$= 4.3 + 0.01 \times 4 = 4.34 \text{ cm}$$

iii. Checking for zero error. Following are some important points to keep in mind before checking zero error:

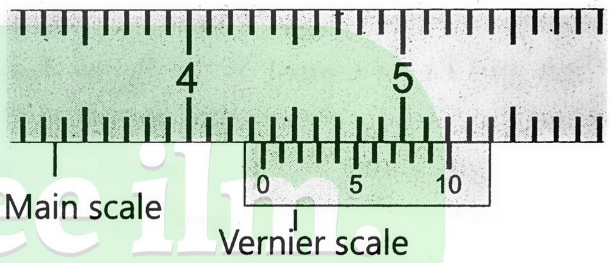

Fig. 1.2 (a)

a) If on joining the jaws A and B, the zeros of the main scale and Vernier scale do not exactly coincide with each other then there is an error in the instrument called **zero error.**

b) If the zero of the Vernier scale is on the right side of the zero of the main scale (Fig.1.2(b)) then this instrument will show slightly more than the actual length. Hence, these zero errors are subtracted from the observed measurement.

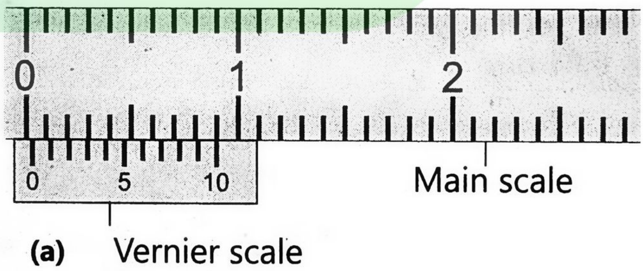

Fig. 1.2 (b)

To find the zero error, note the number of the division of the Vernier scale which is exactly in front of any division of the main scale. Multiply this number with the least count. The resultant number is the zero error of this instrument. The observed reading is corrected by subtracting the zero error from it.

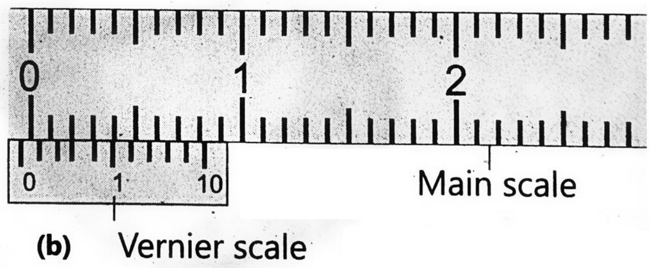

Fig. 1.2 (b)

c) If the zero of the Vernier scale is on the left side of the zero of the main scale (Fig. 1.2(c)), then instrument will show slightly less than the actual length.

Hence, the zero error is added in the observed measurement. For example, if 3 is the number of divisions coinciding with any main scale division then 3 is subtracted from 10 and the result is then multiplied with the least count. Therefore, the zero error in this case will be 0.7 mm. For correction, it is added in the observed reading.

Digital Vernier Caliper: Digital Vernier Calipers has greater precision than mechanical Vernier Calipers. Least count of Digital Vernier Calipers is 0.01 mm.

Q.10. What is screw gauge? What is its pitch and least count? How it is used to measure thickness of an object? OR What is screw gauge? Describe its construction and working.

Ans: Screw Gauge

*A **Screw Gauge** is an instrument used to measure very small lengths, such as the **diameter of a wire** or the **thickness of a metal sheet**.*

Construction:

It consists of two scales:

(a) Main Scale on the sleeve, which has markings of **0.5 mm** each.

(b) Circular Scale on the thimble, which has **50 divisions**. Some screw gauges may have a main scale marking of **1 mm** and **100 divisions** on the thimble.

Pitch and Least Count of the Screw Gauge:

When the thimble makes one complete turn, the spindle moves **0.5 mm (1 scale division)** on the main scale. This movement is called the **pitch** of the screw gauge. The **least count** of the screw gauge is calculated as:

Least count = Pitch of the screw gauge / Number of divisions on the circular scale

Least count = 0.5 mm / 50 = 0.01 mm.

This means the smallest measurement that can be accurately taken using the screw gauge is **0.01 mm**.

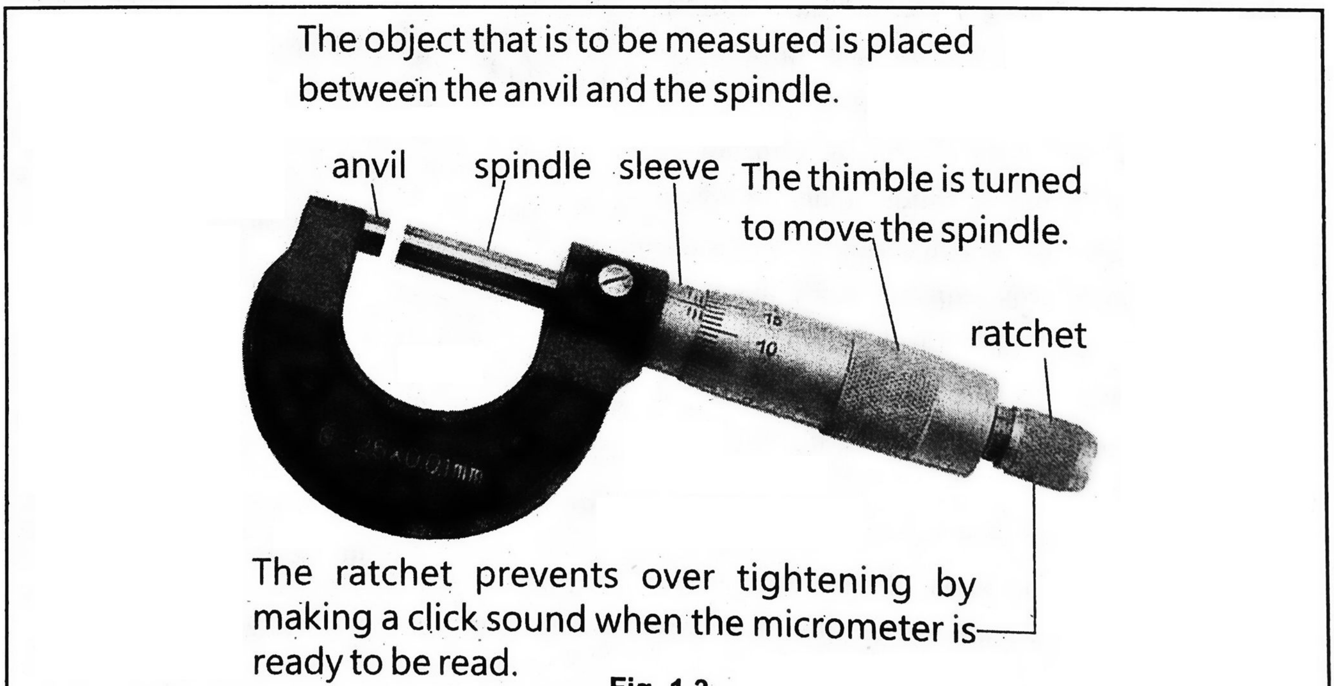

Fig. 1.3

Checking for Zero Error

Zero Error occurs when the zero of the circular scale does not coincide exactly with the horizontal line on the main scale. The following are the cases of zero error detection and correction:

- **No Zero Error**: If the zero of the circular scale coincides with the horizontal line (Fig. 1.4-a), there is **no zero error**.
- **Zero Error Below the Line**: If the zero of the circular scale is **below the horizontal line**, the screw gauge measures slightly more than the actual thickness. In this case, the **zero error** is **subtracted** from the observed measurement (Fig. 1.4-b).
- **Zero Error Above the Line**: If the zero of the circular scale is **above the horizontal line**, the screw gauge measures slightly less than the actual thickness. In this case, the **zero error** is **added** to the observed measurement (Fig. 1.4-c).

By detecting and correcting the zero error, accurate measurements can be ensured using the screw gauge.

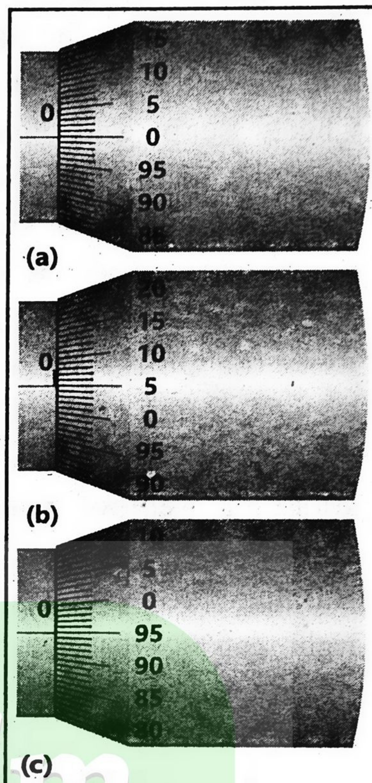

Fig. 1.6

Working:

Measurement Using Screw Gauge:

Suppose when a steel sheet is placed in between the anvil and spindle, the position of circular scale is shown in Fig. 1.4 (b).

(a) Read the marking on the sleeve just before the thimble. It shows 6.5 mm.

(b) Read the circular scale marking which is in line with the main scale. This shows 25. Hence,

$$\text{Thickness} = \text{main scale reading} + (\text{circular scale reading} \times \text{L. C.})$$
$$= 6.5\text{ mm} + 25 \times 0.01\text{ mm}$$
$$= 6.5\text{ mm} + 0.25\text{mm} = 6.75\text{ mm}$$

Q.11. Write a brief note on physical balance.

Ans: Physical Balance

Definition: *A **Physical Balance** is used for measuring the **mass** of an object, and it is based on the principle of levers.* In daily life, we often use the term **weight** to refer to mass, but in **Physics**, mass and weight are distinct concepts. **Mass** refers to the quantity of matter in a body, while **weight** is the force by which the object is attracted to the Earth. The **weight** of an object can be measured using a **spring balance**, whereas the **mass** is determined by comparing the object with known standard masses. This process is known as **weighing**.

Steps for Using a Physical Balance

To weigh an object accurately using a physical balance, follow these steps:

i. **Level the Base**: First, use the levelling screws to adjust the base of the balance so that the **plumb line** is exactly above the pointed mark.

ii. **Check Beam and Pointer**: Turn the knob to raise the pans of the balance. Ensure that the beam is **horizontal** and the **pointer** is at the center of the scale. If not, adjust the balancing screws on the beam to make it horizontal.

iii. **Place the Object**: Place the object to be weighed on the **left pan** of the balance.

iv. **Place Known Weights**: Using **forceps**, place the **standard weights** from the weight box into the **right pan**.

v. **Balance the Beam**: Adjust the weights on the right pan so that the pointer stays at **zero** or oscillates evenly on both sides of the zero of the scale.

vi. **Determine the Mass**: The total of the **standard masses** placed on the right pan gives the **mass** of the object in the left pan.

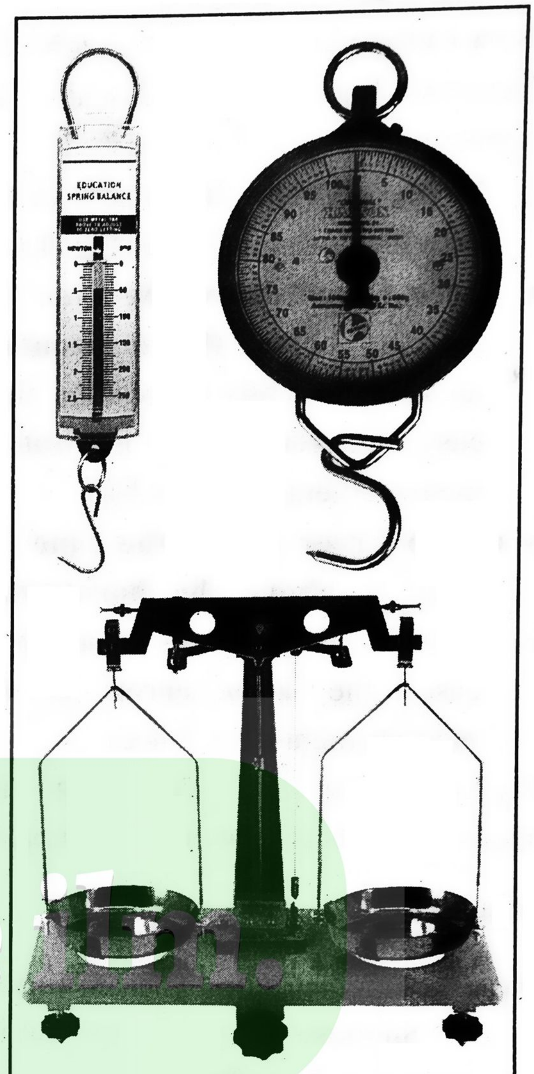

Fig. 1.5

Q.12. Write a brief note on stopwatch.

Ans: Stopwatch

*A **stopwatch** is an instrument used to measure the **duration of time** of an event.* It contains two needles: one for **seconds** and another for **minutes**. The dial of the stopwatch is usually divided into **30 big divisions**, with each of these divisions being further divided into **10 small divisions**. Each **small division** represents **one tenth (1/10) of a second**. Therefore, **one tenth of a second** is the **least count** of the stopwatch.

Fig. 1.6 Mechanical Stopwatch

Fig. 1.7 Digital Stopwatch

Using the Stopwatch

To use the stopwatch, the following steps should be followed:

i. Press the **knob** present on the top of the device to start the stopwatch.

ii. Press the same **knob** again to stop it after the event is measured.

iii. Once the reading is noted, press the **knob** once more to reset the needles back to the **zero position**.

Modern Digital Stopwatches

In modern times, **electronic/digital watches** are available, which can measure time more accurately, down to **one hundredth** of a second. These digital stopwatches offer a higher level of precision compared to traditional mechanical stopwatches.

Q.13. Write a brief note on measuring cylinder.

Ans: Measuring Cylinder

A **measuring cylinder** is a cylindrical container made of **glass** or **transparent plastic**. It is marked with a scale divided into **cubic centimeters (cm or cc)** or **milliliters (mL)**. The measuring cylinder is primarily used to find the **volume of liquids** and **non-dissolvable solids**.

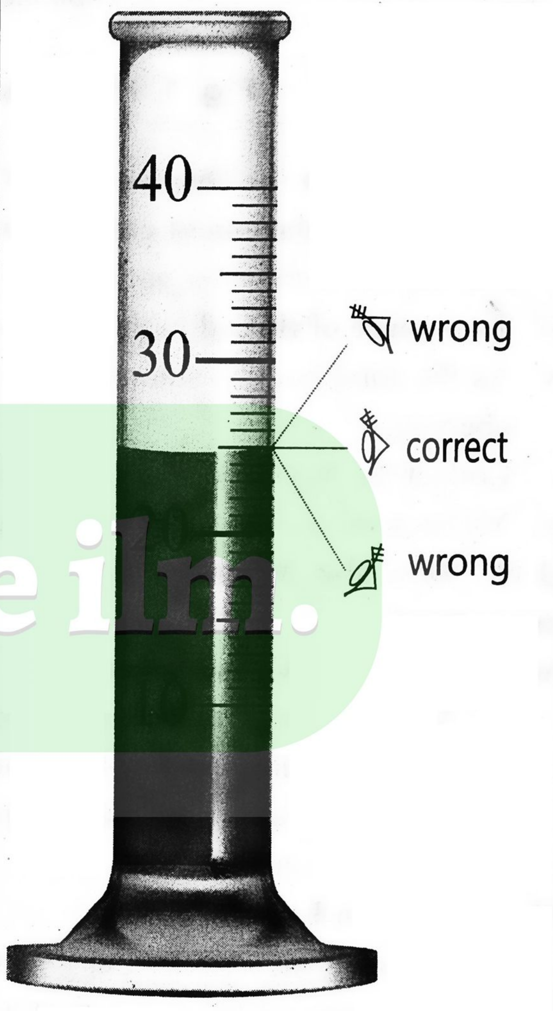

Fig. 1.8
Measuring cylinder

Measuring the Volume of Liquids

To measure the volume of a liquid, the liquid is poured into the measuring cylinder, and the level of the liquid marks the volume. To read the volume accurately, the cylinder must be placed on a **horizontal surface**, and the **eye must be level with the meniscus** of the liquid surface. The **meniscus** is the curve at the top of the liquid surface. For **water**, the meniscus forms a **concave surface**, and the reading is taken at the **bottom edge** of the concave surface.

Reading the Meniscus of Mercury

When measuring **mercury**, the liquid forms a **convex surface**, which curves **upward**. In this case, the reading is taken from the **top edge** of the convex surface.

Measuring the Volume of Solids

The measuring cylinder can also be used to measure the **volume of solids** by observing the displacement of the liquid when the solid is added.

Q.14. Describe displacement can method for finding volume of a solid.

Ans: Displacement Can Method

The **displacement can method** is used when the solid body cannot fit into the measuring cylinder. Instead, a **displacement can** with a wide opening is used to measure the volume of the solid.

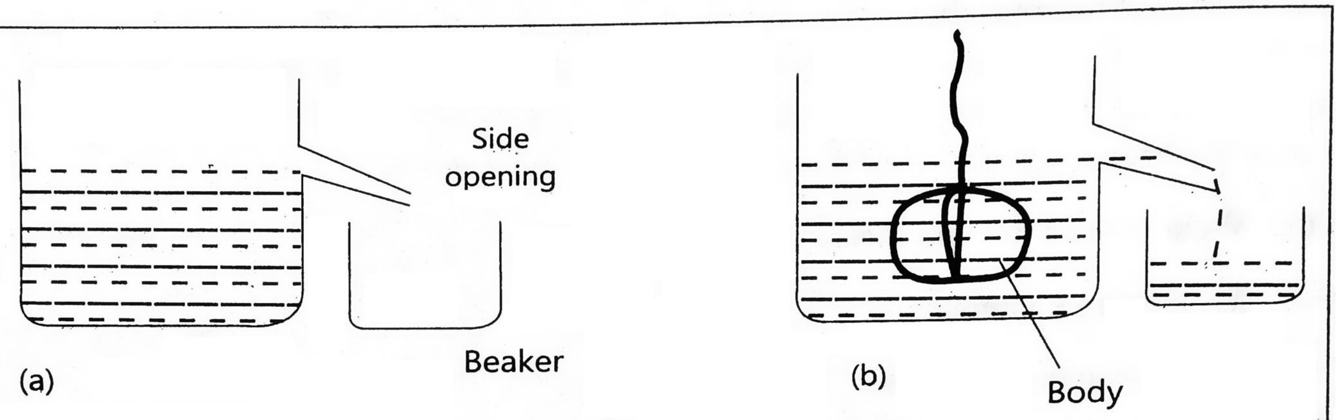

Fig. 1.9 Displacement can or Overflow can

Steps Involved in the Displacement Can Method

i. Place the **displacement can** on a **horizontal table**.
ii. Fill the can with water until it starts **overflowing** through its opening.
iii. Tie a **piece of thread** to the solid body and gently lower it into the displacement can.
iv. As the solid body is submerged, it **displaces water**, which flows out through the side opening.
v. Collect the displaced water in a **beaker**.
vi. Measure the volume of the displaced water using a **measuring cylinder**.

Q.15. Describe different types of errors in measurement and how can they be minimized?

Ans: Errors in Measurement

Measurements made using tools and instruments are not always perfect. These measurements inherit errors, which cause them to differ from their true values. The goal is to minimize these errors as much as possible. There are three types of experimental errors that affect measurements:

(i) Human Errors

Human errors occur due to personal performance limitations, such as the inability to precisely estimate the position of a pointer on a scale. These errors can also arise from faulty procedures, like improper reading of the scale. **In timing experiments**, human reaction time in starting or stopping the clock also affects the measurement.

Minimizing Human Errors:

- Ensuring proper **training**, techniques, and procedures to handle instruments.
- Avoiding **environmental distractions** to maintain focus.
- Using **automated or digital instruments** can significantly reduce human error.

(ii) Systematic Errors

Systematic errors refer to errors that influence all measurements of a particular type in the same way, resulting in consistent differences in readings. These errors may arise from factors such as **zero error**, poor calibration of instruments, or incorrect markings on the scale.

Minimizing Systematic Errors:

- Comparing the instrument with another one known to be more accurate.
- Applying a **correction factor** to adjust the measurements.

(iii) Random Errors

Random errors occur when repeated measurements of the same quantity produce different results under the same conditions. These errors are caused by unpredictable factors, and the experimenter has little or no control over them. They may arise due to fluctuations in **environmental conditions**, such as changes in temperature, pressure, humidity, or voltage.

Minimizing Random Errors:

- Taking multiple readings and calculating the **average** or **mean** value.
- For example, when measuring the time of oscillations of a pendulum, the time for several oscillations (e.g., 30 oscillations) is measured, and the average time for one oscillation is then calculated.

Q.16. Describe concept of uncertainty in measurement.

Ans: Uncertainty in Measurements

There is no such thing as a perfect measurement. Whenever a physical quantity is measured, except for counting, there is always some uncertainty in the determined value due to the limitations of the instrument used. This uncertainty arises from various reasons, with one key factor being the type of instrument employed. Every measuring instrument is calibrated to a certain smallest division, which limits the degree of accuracy that can be achieved when using it.

Instrument Limitations and Uncertainty

Consider the example of measuring the length of a straight line using a meter rule calibrated in millimeters. If the endpoint of the line lies between the 10.3 cm and 10.4 cm marks, the reading is taken according to the following convention:

- If the endpoint of the line does not touch or cross the midpoint of the smallest division, the reading is confined to the previous division.
- If the endpoint touches or crosses the midpoint, the reading is extended to the next division.

In this example, the maximum uncertainty is ± **0.05 cm**, which is equivalent to ± **0.1 cm**, representing half of the least count of the instrument, divided into two parts—half above and half below the recorded reading.

Significant Figures and Uncertainty

The uncertainty or accuracy of the measured value can be conveniently indicated using **significant figures**. This method expresses the uncertainty in the measurement by indicating the degree of precision in the recorded value. Significant figures help to convey the limits of accuracy in the measurement, providing a clear understanding of the measurement's reliability.

Q.17. What are significant figures? Explain general rules for writing significant figure with the help of examples.

Ans: Significant Figures

"In any measurement, the accurately known digits and the first doubtful digit are known as significant figures."

Explanation:

Significant figures are used to reflect the degree of uncertainty in a measurement, which occurs due to limitations in the measuring instrument. While we can count objects like candies in a jar exactly, we cannot measure certain physical quantities, such as the height of a jar, with perfect accuracy. Every measurement includes some level of uncertainty, and significant figures help convey this uncertainty by recording all the reliably known digits along with the first doubtful or uncertain digit.

For example, when measuring the length of a rod between 4.6 cm and 4.7 cm, the first student might estimate it to be 4.6 cm, and the second student might estimate it as 4.7 cm. Both students agree on the first digit (4), but the second digit is uncertain and was estimated, making it a "doubtful digit." In this case, the significant figures would include both the accurately known digit and the first doubtful digit.

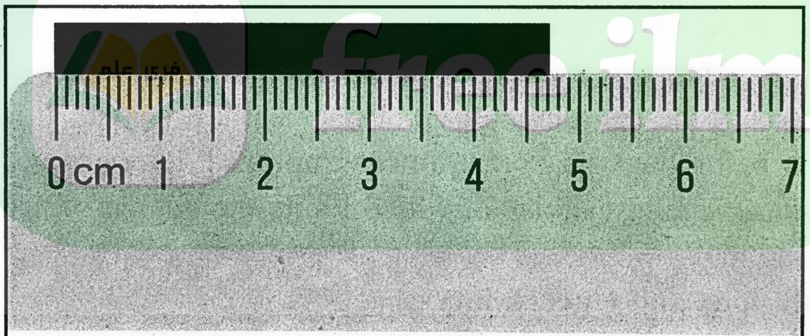

Fig. 1.10

Rules for Determining Significant Figures:

The following rules help to determine the number of significant figures in a measurement:

i. **All digits from 1 to 9 are always significant.**
For example, in the measurement 5.06 m, all digits (5, 0, and 6) are significant, so it has 3 significant figures.

ii. **Zeros between non-zero digits are considered significant.**
For instance, in 5.06 m, the zero between 5 and 6 is significant, so it has 3 significant figures.

iii. **Leading zeros (zeros before the first non-zero digit) are not significant.**
For example, in 0.0034 m, the zeros before 3 are not significant, so it has 2 significant figures.

iv. **Zeros to the right of a decimal point are considered significant.**
For example, in 2.40 mm, the zero after the decimal point counts as significant, so it has 3 significant figures.

v. **In scientific notation, all digits before the exponent are significant.**
For example, in 3.50×10^{-4} m, the significant figures are 3 (3, 5, and 0), as all digits before the exponent are considered significant.

Q.18. Differentiate between precision and accuracy in physical measurement.

Ans: Precision and Accuracy

In physical measurements, precision and accuracy are two distinct concepts that must be clearly understood.

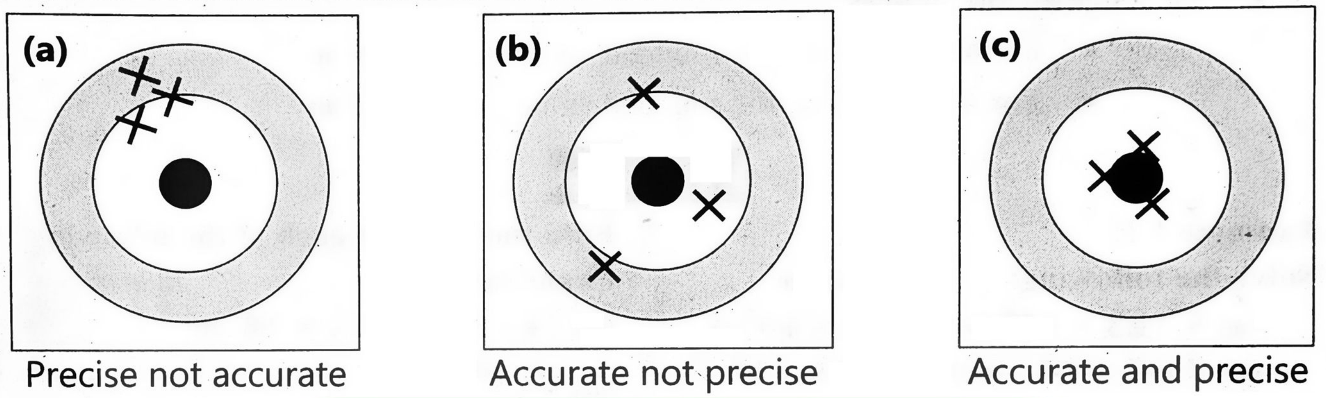

Fig. 1.11

i. **Precision** refers to how close together a group of measurements are to each other. It shows the consistency or repeatability of the measurements. For example, if arrows are shot at a target and hit near each other (Fig. 1.16 a), the measurements are considered precise, regardless of whether they are near the bullseye or not.

ii. **Accuracy**, however, refers to how close the measured value is to the accepted or true value. In the example of a target (Fig. 1.16 b), if the arrows hit near the bullseye, then the measurements are considered accurate because they reflect the true value of the measurement.

Explanation:

In conclusion, precision is about the closeness of repeated measurements to each other, while accuracy is about how close those measurements are to the true value, with both being influenced by the type of instrument used and the number of significant figures recorded.

Q.19. Explain rounding off number in scientific measurement.

Ans: Rounding Numbers to Significant Figures

When rounding numbers to a specified number of significant figures, the following rules should be applied:

i. **If the last digit is greater than 5**, increase the retained digit by one.
ii. **If the last digit is less than 5**, retain the retained digit as it is.
iii. **If the last digit is exactly 5**, apply the following:

- **If the digit before the 5 is odd**, increase the last retained digit by one.

- **If the digit before the 5 is even**, leave the last retained digit unchanged.

These rules ensure that the rounded value reflects the correct level of precision.

Examples of Rounding to Significant Figures

- **Rounding to 2 significant figures**:
- For 2.512×10^3 m, the rounded value is **2.5×10^3 m**
- For 3.4567×10^4 kg, the rounded value is **3.46×10^4 kg**

Examples of Rounding with the Digit 5

- **To 2 significant figures**:
    - For 4.45×10^2 m, the rounded value is **4.4×10^2 m**
    - For 4.55×10^2 m, the rounded value is **4.6×10^2 m**