

Units and Measurements

Measurement of Length

Direct Methods

Direct methods of measuring length involve using instruments to measure the physical length of an object directly. Some common instruments used in direct measurement are:

1. **Metre Scale:** Used for measuring lengths from 1 mm to a few meters. It's a common instrument found in most laboratories and households.
2. **Vernier Calipers:** Used for measuring lengths with an accuracy up to 0.1 mm. It is especially useful for measuring internal and external dimensions of objects.
3. **Screw Gauge (Micrometer):** Used for measuring very small lengths with an accuracy of up to 0.01 mm. It is particularly useful for measuring the diameter of thin wires or the thickness of small objects.

Measurement of Large Distances (Parallax Method)

When measuring large distances, such as the distance between a planet and Earth, direct methods are not feasible. The parallax method is an indirect method used for such measurements.

Principle of Parallax Method:

- **Parallax:** The apparent shift in the position of an object when viewed from two different positions.
- **Baseline:** The distance between the two observation points.

Steps in Parallax Method:

1. **Observation Points:** Choose two observation points (A and B) on Earth, separated by a known distance $AB = b$.
2. **Observation:** Observe the distant object (e.g., a planet) from both points A and B simultaneously.
3. **Angle Measurement:** Measure the angle of inclination θ between the two lines of sight from A and B to the object.
4. **Distance Calculation:**

$$D = \frac{b}{\theta}$$

where D is the distance to the object and θ is in radians.

This method is based on the principle that the farther the object, the smaller the parallax angle.

Estimation of Very Small Distances

When measuring very small distances, specialized techniques and instruments are required:

1. **Electron Microscopes:** Use electron beams to achieve high resolution and can measure distances as small as 0.1 nm (nanometers). They are essential for observing atomic and subatomic structures.
2. **Tunneling Microscopy:** Scanning Tunneling Microscopy (STM) can measure distances at the atomic level by using the concept of quantum tunneling. It provides atomic-scale images of surfaces.
3. **Interferometry:** Utilizes the interference of light waves to measure very small distances with high precision. This technique is widely used in various fields including physics, engineering, and astronomy.

Example: Measuring the Size of a Molecule (Oleic Acid):

- **Step 1:** Dissolve a known volume of oleic acid in alcohol to make a solution.
- **Step 2:** Spread a drop of this solution on the water surface, forming a thin, circular film.
- **Step 3:** Measure the diameter of the film to calculate its area.
- **Step 4:** Knowing the volume of the drop and the area of the film, estimate the thickness (which corresponds to the size of the molecule).

Range of Lengths

The sizes of objects we encounter in the universe vary over a wide range. The following table gives an idea of the range and order of lengths:

| Object/Phenomenon | Length (m) |
|-------------------------------------|------------|
| Size of a proton | 10^{-15} |
| Size of an atomic nucleus | 10^{-14} |
| Size of a hydrogen atom | 10^{-10} |
| Length of typical virus | 10^{-8} |
| Wavelength of visible light | 10^{-7} |
| Size of red blood cell | 10^{-5} |
| Thickness of a sheet of paper | 10^{-4} |
| Height of Mount Everest | 10^4 |
| Radius of the Earth | 10^7 |
| Distance to the Moon | 10^8 |
| Distance to the Sun | 10^{11} |
| Distance to the nearest star | 10^{16} |
| Size of the Milky Way Galaxy | 10^{21} |
| Distance to the observable universe | 10^{26} |

This range demonstrates the vast diversity in the sizes of objects and distances we encounter, from the microscopic scale of atoms to the astronomical scale of the universe. Understanding this range is crucial for applying appropriate measurement techniques and instruments for different scales.