to sign and size. These can arise due to random and unpredictable fluctuations in experimental conditions (e.g. unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc), personal (unbiased) errors by the observer taking readings, etc. For example, when the same person repeats the same observation, it is very likely that he may get different readings everytime.

Least count error

Def. of Least count

The smallest value that can be measured by the measuring instrument is called its **least count**. All the readings or measured values are good only up to this value.

The **least count error** is the error associated with the resolution of the instrument. For example, a vernier callipers has the least count as 0.01 cm; a spherometer may have a least count of 0.001 cm. Least count error belongs to the category of random errors but within a limited size; it occurs with both systematic and random errors. If we use a metre scale for measurement of length, it may have graduations at 1 mm division scale spacing or interval.

Why are the observations repeated several times?

Using instruments of higher precision, improving experimental techniques, etc., we can reduce the least count error. Repeating the observations several times and taking the arithmetic mean of all the observations, the mean value would be very close to the true value of the measured quantity.

2.6.1 Absolute Error, Relative Error and Percentage Error

(a) Suppose the values obtained in several measurements are $a_1, a_2, a_3...., a_n$. The arithmetic mean of these values is taken as the best possible value of the quantity under the given conditions of measurement as :

$$a_{mean} = (a_1+a_2+a_3+...+a_n)/n \qquad (2.4)$$

or,

$$a_{mean} = \sum_{i=1}^{n} a_i / n \qquad (2.5)$$

This is because, as explained earlier, it is reasonable to suppose that individual measurements are as likely to overestimate as to underestimate the true value of the quantity.

The magnitude of the difference between the individual measurement and the true value of the quantity is called the absolute error of the measurement. This is denoted by $|\Delta a|$. In absence of any other method of knowing true value, we considered arithmatic mean as the true value. Then the errors in the individual measurement values from the true value, are

Def.

$$\Delta a_1 = a_1 - a_{mean},$$
$$\Delta a_2 = a_2 - a_{mean},$$
$$.... \quad .... \quad ....$$
$$.... \quad .... \quad ....$$
$$\Delta a_n = a_n - a_{mean}$$

The Δa calculated above may be positive in certain cases and negative in some other cases. But absolute error $|\Delta a|$ will always be positive.

(b) The arithmetic mean of all the *absolute errors* is taken as the *final* or *mean absolute error* of the value of the physical quantity a. It is represented by Δa_{mean}.

Def.

Thus,

$$\Delta a_{mean} = (|\Delta a_1|+|\Delta a_2|+|\Delta a_3|+...+|\Delta a_n|)/n \qquad (2.6)$$

$$= \sum_{i=1}^{n} |\Delta a_i|/n \qquad (2.7)$$

If we do a single measurement, the value we get may be in the range $a_{mean} \pm \Delta a_{mean}$

i.e. $a = a_{mean} \pm \Delta a_{mean}$

or,

$$a_{mean} - \Delta a_{mean} \le a \le a_{mean} + \Delta a_{mean} \qquad (2.8)$$

This implies that any measurement of the physical quantity a is likely to lie between $(a_{mean} + \Delta a_{mean})$ and $(a_{mean} - \Delta a_{mean})$.

(c) Instead of the absolute error, we often use the **relative error** or the **percentage error** (δa). ***The relative error is the ratio of the*** **mean absolute error Δa_{mean} to the mean value a_{mean} of the quantity measured.**

Def.