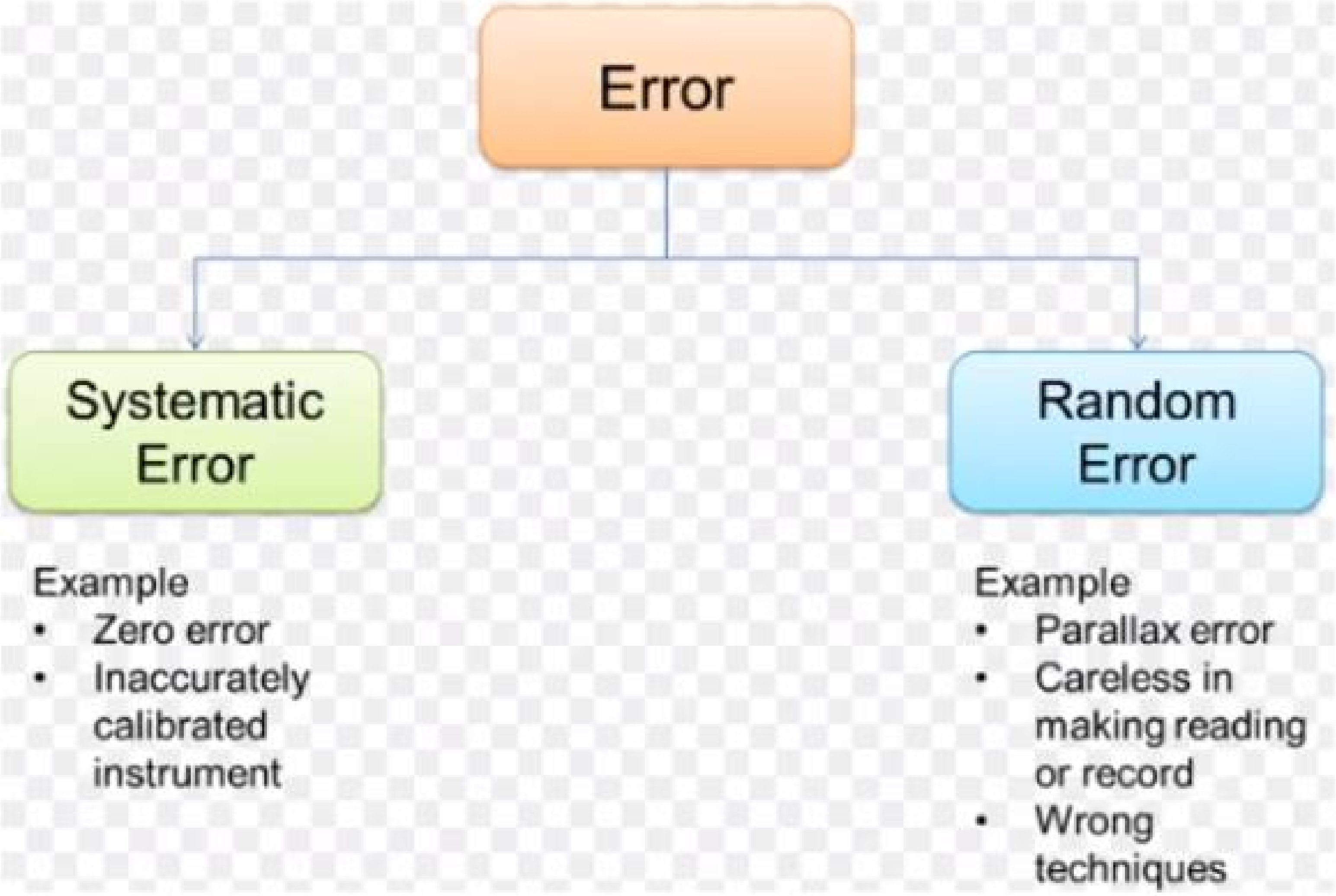
Books:

- Physics by Halliday, Resnik and Krane, Vol. 1 & 2, edition 6^{th} or higher.
- Physics for engineers and scientists by Serway and Jewet, edition 6^{th} .
- Fundamentals of Electronics by Floyd.
- Vector Analysis by Schaum Series

ERRORS

- Measurement = (best estimate ± uncertainty) units
- Error is the difference between the actual value and calculated value of any physical quantity.



Measurements and Error Analysis

LECTURE 1 (P1)

Applied Physics PH-122

TYPES OF ERROR

Random errors or errors due to unknown causes

- Random error is **said to** occur when **repeated measurements of the quantity, give** different values under the same conditions.
- **Reasons of occurrence:**
  It is due to some unknown causes.
- **Elimination of error:**
  Repeating the measurement several times and **taking an average can reduce the** effect of random errors.

Systematic errors or errors due to known causes

- Systematic error refers to an effect that influences all measurements of a particular quantity equally it produces a consistent difference in readings
- **Reason of occurrence**
  It occurs to some definite rule. It may occur due to zero error of instruments, poor calibration of instruments or incorrect markings etc.
- **Elimination of error**
  Systematic error can be reduced by comparing the instruments with another which is known to be more accurate Thus for systematic error a correction factor can be applied

Some important terms

- Tolerance interval (±) : To determine the tolerance add and substract one half of the precision (Least Count) of the measuring instrument for example if the length is measured by ruler is 5.6cm and the L.C is 0.1 cm we can write the measurement as 5.6±0.05
- Observed/calculated value: A value, either observed or calculated from observations. e.g. the value obtained using a ruler to measure length, or the electronic balance to measure mass, or a calculation of the density based upon these.
- Accuracy: A measure of how close the observed value is to the true value.
- Absolute error: |Xobs – Xtrue|, is always positive.
- Relative error: |Xobs – Xtrue| ÷ Xtrue, Accuracy is often reported quantitatively by using relative error.
- Example: m = 75.5 ± 0.5 g, If the true value for m is 80g, then the relative error is: | | 75.5 – 80|/80 = 0.056 = 5.6%
- % error : relative error × 100

Error Estimation

Independent and dependent errors

Independent

- If we measure the mass and find 13.0 ± 0.1 g. This is an independent error, because it comes from a different measurement, made with a different piece of equipment.
- If the errors are independent (they have different, uncorrelated sources) they add in quadrature.

Dependent

- The diameter of a solid spherical object is 18.0 ± 0.2 mm. The volume, calculated from the usual formula, is 3.1 ± 0.1 cm3 (check this, including the error). These errors are dependent.
- If the error are dependent they add linearly.

If the errors are dependent they add linearly

When	Example	Method
Adding or subtracting	$l = x + x$ $y = x_1 - x_2$ $p = 2(l + h)$, when the dominant error is a systematic error common to the measurement of l and h	Add absolute errors $\Delta y = \Delta x + \Delta x = 2\Delta x$ $\Delta y = \Delta x_1 + \Delta x_2$ $\Delta p = 2(\Delta l + \Delta h)$ *Note the plus sign*
Multiplying or dividing	$a = b \times c$ $v = l \times h \times b$, where the dominant error in each is a systematic error common to l, h, b	Add fractional/percentage errors $\frac{\Delta a}{a} = \frac{\Delta b}{b} + \frac{\Delta c}{c}$ $\frac{\Delta v}{v} = \frac{\Delta l}{l} + \frac{\Delta h}{h} + \frac{\Delta b}{b}$

If the errors are independent they add in quadrature

Operation	Example	Method
Adding or subtracting	$z = x + y$ $p = 2(l - h)$	Add absolute errors in quadrature. $\Delta z = \sqrt{(\Delta x)^2 + (\Delta y)^2}$ $\Delta p = 2\sqrt{(\Delta l)^2 + (\Delta h)^2}$
Multiplying or dividing	$z = x \times y$ $v = l \times h \times b$	Add fractional (percentage) errors in quadrature. $\frac{\Delta z}{z} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2}$ $\frac{\Delta v}{v} = \sqrt{\left(\frac{\Delta l}{l}\right)^2 + \left(\frac{\Delta h}{h}\right)^2 + \left(\frac{\Delta b}{b}\right)^2}$

Examples

- If a physical quantity is represented by a relation between other physical quantities having power e.g. $P = ka^x b^y c^z$, where k is constant and x, y & z are numerical values. Then error will be given by:

$$\frac{dP}{P} = x\frac{da}{a} + y\frac{db}{b} + z\frac{dc}{c}$$

Thus it is evident that the quantity with the highest power will contribute most significantly.

Examples

- A capacitor has a capacitance of $C = 2 \pm 0.1F$ whereas the applied voltage is $V = 25 \pm 0.5volts$. Find the charge on capacitor and error in it.
- $Q = CV = 2 * 25 = 50\ coulumb.$
- $\frac{dQ}{Q} = \frac{dC}{C} + \frac{dV}{V}; \frac{dQ}{50} = \pm(\frac{0.1}{2} + \frac{0.5}{25}); dQ = \pm 3.5$
- $Q = (50 \pm 3.5)coulomb$