BENHA UNIVERSITY
FACULTY OF ENGINEERING (SHOUBRA)
ELECTRONICS AND COMMUNICATIONS ENGINEERING

ECE 211

Measurements and Instrumentations

(2022 - 2023) 1^{st} term

Lecture 1: Measurement Errors (part1).

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Outlines

Chapter 1:Measurement Systems, Units, and Standards

1.1 SI Mechanical units:

- **Fundamental Units:**

  Length (L): meter (m), Mass (M): kilogram (kg), Time (T): second (s)

- **Derived Units:**

  Area: Meter Squared

  Force: Newton (N) ⇨ Force = mass × acceleration

  Work: Joule (J) ⇨ Work = force × distance

  Power: Watt (W) ⇨ $power = \frac{work}{time}$

TABLE 1-2 SI Units, Symbols, and Dimensions

Quantity	Symbol	Unit	Unit symbol	Dimensions
Length	l	meter	m	$[L]$
Mass	m	kilogram	kg	$[M]$
Time	t	second	s	$[T]$
Area	A	square meter	m^2	$[L^2]$
Volume	V	cubic meter	m^3	$[L^3]$
Velocity	v	meter per second	m/s	$[LT^{-1}]$
Acceleration	a	meter per sec per sec	m/s^2	$[LT^{-2}]$
Force	F	newton	N	$[MLT^{-2}]$
Pressure	p	newton per square meter	N/m^2	$[ML^{-1}T^{-2}]$
Work	W	joule	J	$[ML^2T^{-2}]$
Power	P	watt	W	$[ML^2T^{-3}]$

1.2 Scientific Notation and Metric Prefixes:

- When working in electronics it is common to encounter very small and very large numbers.
- **Scientific Notation** is a means of using single-digit numbers plus powers of ten to express very large and very small numbers.

$10\,000 = 1 \times 10 \times 10 \times 10 \times 10 = 1 \times 10^4$ $\qquad$ $0.015 = 1.5 \times 10^{-2}$

- **Metric Prefix** : a letter symbols for the various multiples and submultiples of 10.

TABLE 1-1 Scientific Notation and Metric Prefixes

Value	Scientific notation	Prefix	Symbol
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	**giga**	**G**
1 000 000	10^{6}	**mega**	**M**
1000	10^{3}	**kilo**	**K**
100	10^{2}	hecto	h
10	10	deka	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	**milli**	**m**
0.000 001	10^{-6}	**micro**	**μ**
0.000 000 001	10^{-9}	**nano**	**n**
0.000 000 000 001	10^{-12}	**pico**	**p**

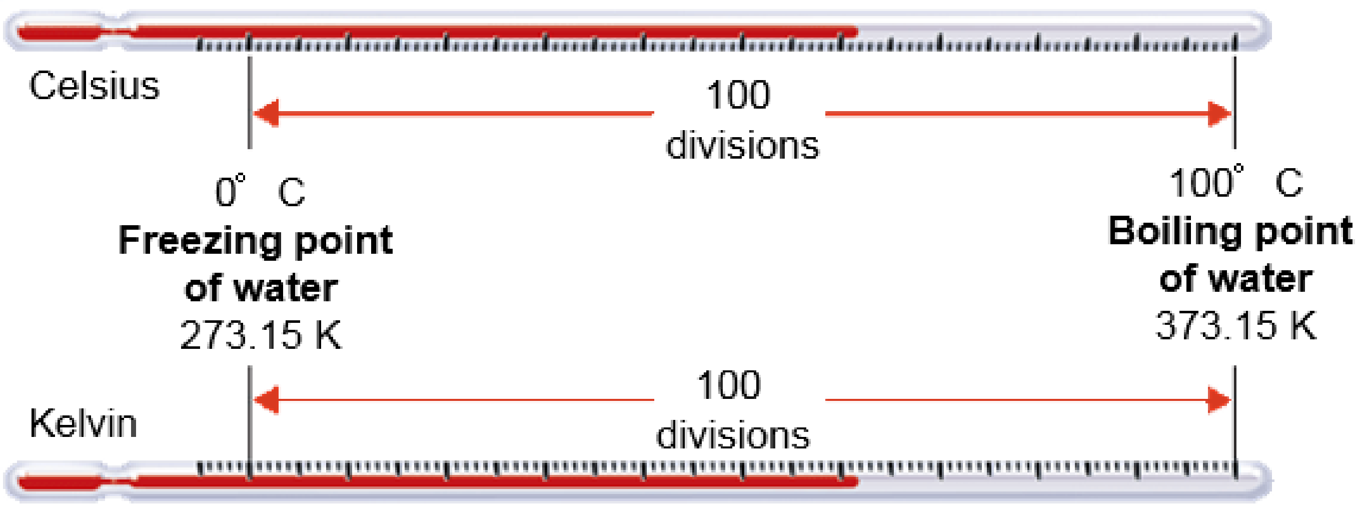
1.3 SI Electrical units:

- Electric current (I): A
- Electric charge (Q): C ⇨ Charge = current × time
- Voltage (V): V ⇨ $V = \frac{P}{I} = \frac{[ML^2T^{-3}]}{[I]}$
- Resistance (R): ohm ⇨ $R = \frac{V}{I} = \frac{[ML^2T^{-3}I^{-1}]}{[I]}$

Quantity	Symbol	Unit	Unit symbol	Dimensions
Electric current	I	ampere	A	$[I]$
Electric charge	Q	coulomb	C	$[IT]$
Emf	V	volt	V	$[ML^2T^{-3}I^{-1}]$
Electric field strength	ξ	volt per meter	V/m	$[MLT^{-3}I^{-1}]$
Resistance	R	ohm	Ω	$[ML^2T^{-3}I^{-2}]$
Capacitance	C	farad	F	$[M^{-1}L^{-2}T^4I^2]$
Inductance	L	henry	H	$[ML^2T^{-2}I^{-2}]$
Magnetic field strength	H	ampere per meter	A/m	$[IL^{-1}]$
Magnetic flux	Φ	weber	Wb	$[ML^2T^{-2}I^{-1}]$
Magnetic flux density	B	tesla	T	$[MT^{-2}I^{-1}]$

1.4 SI Temperature Scales:

- There are two temperature scales, the **Celsius** scale and the **Kelvin** (absolute) scale.



- **absolute zero:** the zero point on the Kelvin temperature scale, equivalent to –273.15°C
- In some countries as the United States, temperatures are usually given in **degrees Fahrenheit**.

$K = °C + 273$ $\quad$ $°C = K - 273$ $\quad$ $°C = \frac{°F - 32}{1.8}$

Outlines

- Ch.1 : Measurement Systems, Units, and Standards.
- Ch.2 : Measurement Errors

Chapter 2: Measurement Errors

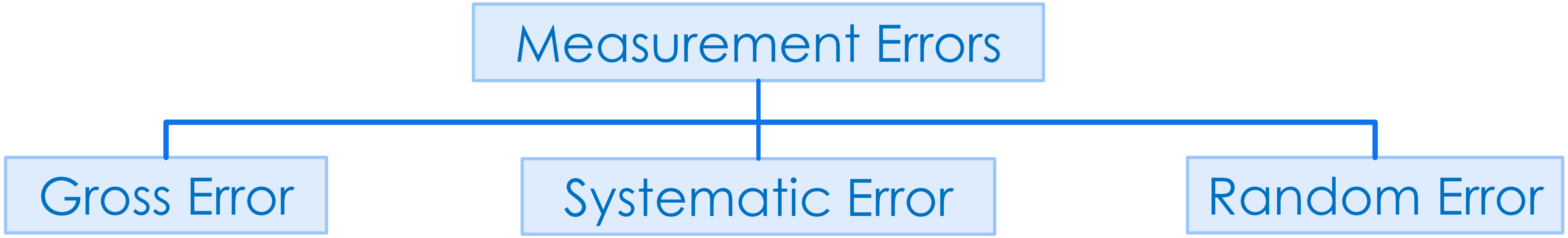
1. Types of Measurement Errors.
2. Absolute and Relative Errors.
3. Measurements Characteristics.
4. Measurement Error Combinations.

Introduction:

- No electronic component or instrument **is perfectly accurate;** all have some error or inaccuracy.
- These errors are introduced due to either **defect** in the instrument, **wrong observance**, or **environmental factors**.
- These errors could combine to either:
  - Completely cancel each others.
  - Create greater errors in measurement (Worst case)
- The worst case should always consider while performing measurement, where these errors could combine to create larger error.

2.1 Measurement Errors types:

Measurement errors can be categorized into three types:

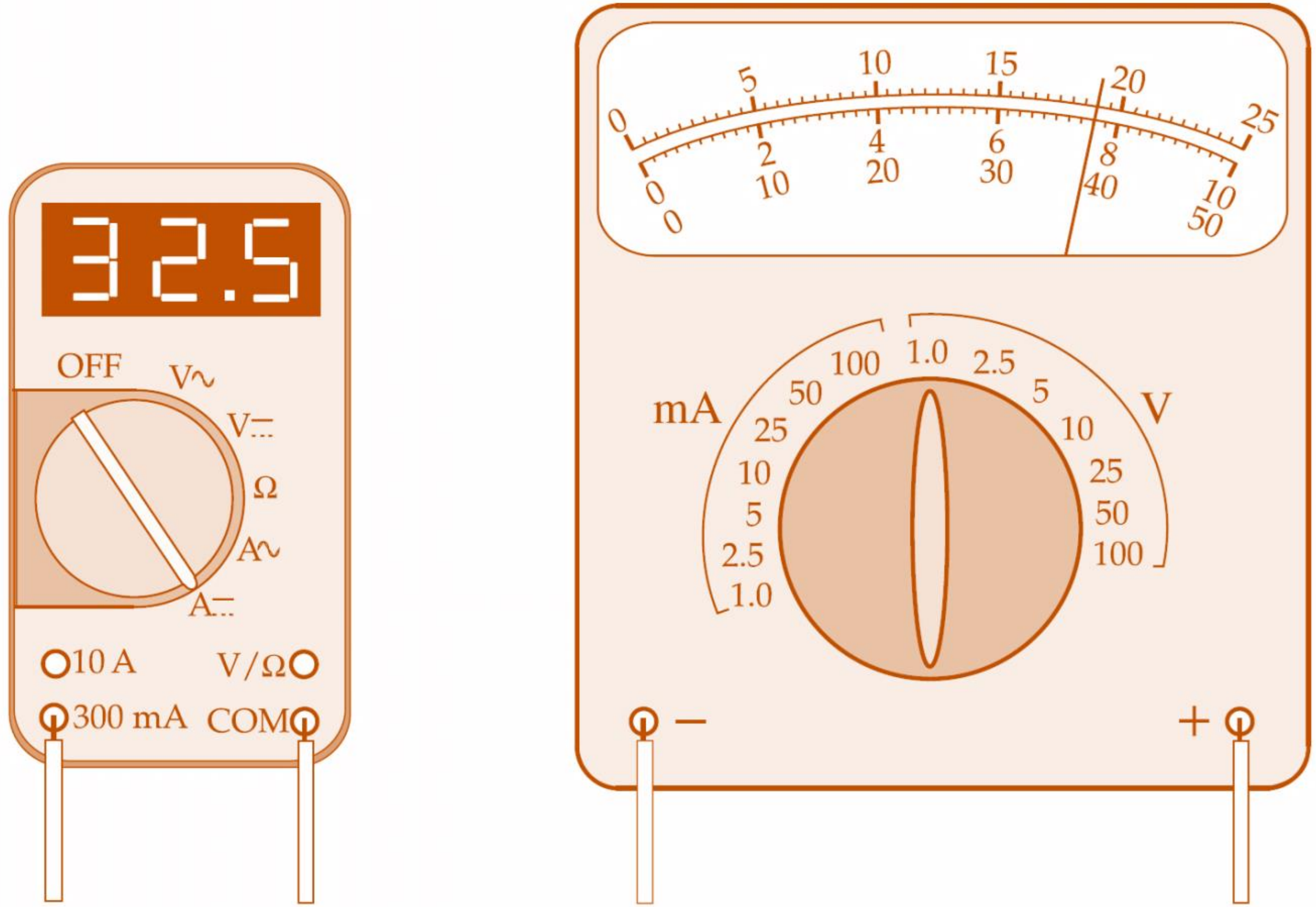


Gross Error (Human Error)

Errors due to **human mistakes** in using instruments, recording observations, and calculating measurement results.

Example

- Misunderstanding the unit in case of digital devices (21 V instead of 21 mV).
- A wrong scale may be chosen in analog instruments.
- Transpose of the readings while recording. (24.9 mV instead of 29.4 mV).
- Observational Errors: Errors introduced by the observer as the **parallax error**.



(a) Digital instrument indicating 32.5 mA

(b) Analog instrument indicating 0.76 V

Figure 2-1 Serious measurement errors can occur if an instrument is not read correctly. The digital instrument is on a 300 mA range, so its reading is in milliamperes. For the analog meter, the range selection must be noted, and the pointer position must be read from the correct scale.

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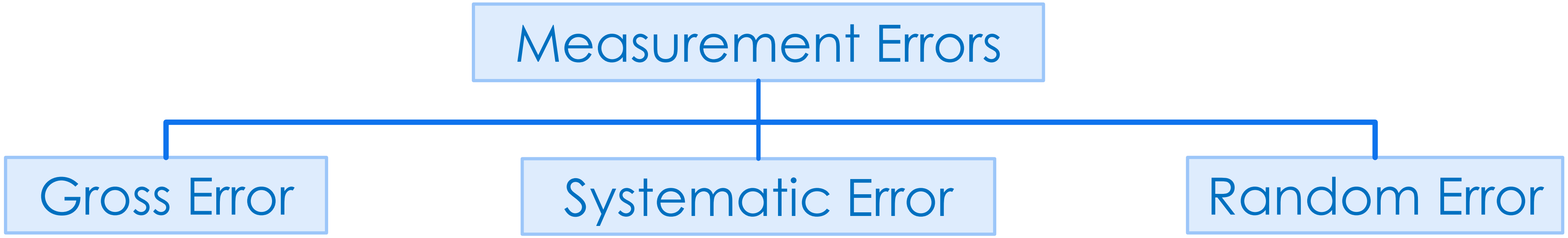
Measurement errors can be categorized into three types:



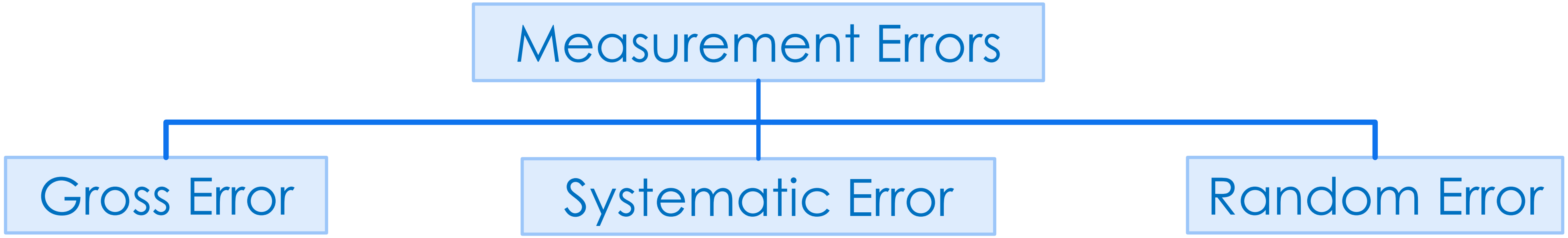
Systematic Error

Errors due to **problems with instruments.**

- **Instrument Errors:** May be due to incorrect device calibration.
- **Environmental Errors:** Change in environnemental conditions may change some of device parameters.

2.1 Measurement Errors types:

Measurement errors can be categorized into three types:



Random Error
Errors due to **unknown factors.**

- These errors are relatively **small.**
- These errors can be **reduced** by **increasing** the number of readings and using arithmetic mean.

Chapter 2: Measurement Errors

1. Types of Measurement Errors.
2. Absolute and Relative Errors.
3. Measurements Characteristics.
4. Measurement Error Combinations.

2.2 Absolute and Relative Errors:

- The error in measuring instruments can be represented in two ways: **Absolute** and **Relative**

Absolute Error (Δe)

It is defined as the difference between the measured A_m and the true A_t values.

$$\Delta e = A_m - A_t$$

Example

An ammeter reads 6.7 A and the true value of the current is 6.54 A. The absolute error is

$$\Delta e = A_m - A_t = 6.7 - 6.54 = 0.16\ A$$

2.2 Absolute and Relative Errors:

Relative Error (e_r)

It is defined as the ratio of the absolute error Δe to the true value A_t of the quantity being measured.

$$e_r = \frac{\Delta e}{A_t}$$

Percentage error

$$\%e_r = e_r \times 100 = \frac{\Delta e}{A_t} \times 100$$

Example

The current through a resistor is 2.5 A, but the measurement yields a value of 2.45 A.

The absolute error is

$$\Delta e = A_m - A_t = 2.45 - 2.5 = -0.05A$$

The relative error

$$e_r = \frac{\Delta e}{A_t} = \frac{-0.05}{2.5} = -0.02$$

The percentage relative error

$$\%e_r = e_r \times 100 = -2\%$$

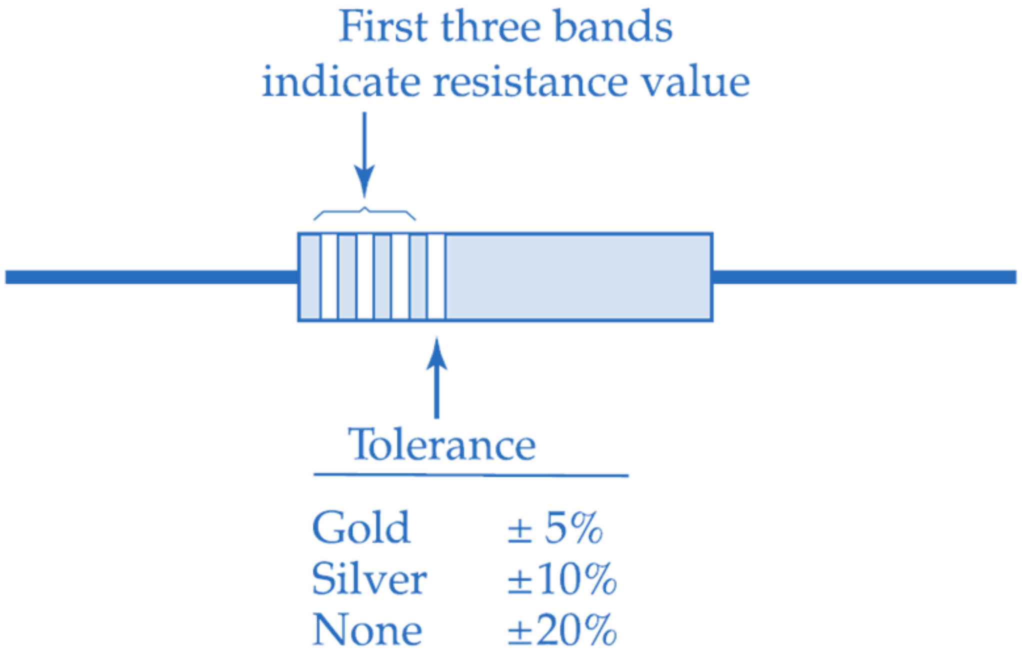


Figure 2-2 The relative error in a measured or specified quantity is expressed as a percentage of the quantity. The absolute error is determined by converting the relative error into an absolute quantity.

END OF LECTURE

BEST WISHES