Benha University
Faculty of Engineering (Shoubra)
Electronics and Communications Engineering

# ECE 211
# Electrical and Electronic Measurements
# (2020-2021)

## Lecture 1: Introduction and Measurement Errors

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# Course Introduction:
## Electrical and Electronic Measurements

- This course will cover mainly the **electronic instruments**, which are useful for measuring either **electrical quantities or parameters**.


Voltmeter


Ammeter


Ohmmeter


Digital Multimeter

# Course Introduction:
## Electrical and Electronic Measurements

The course consists of the following parts: (The first seven weeks)

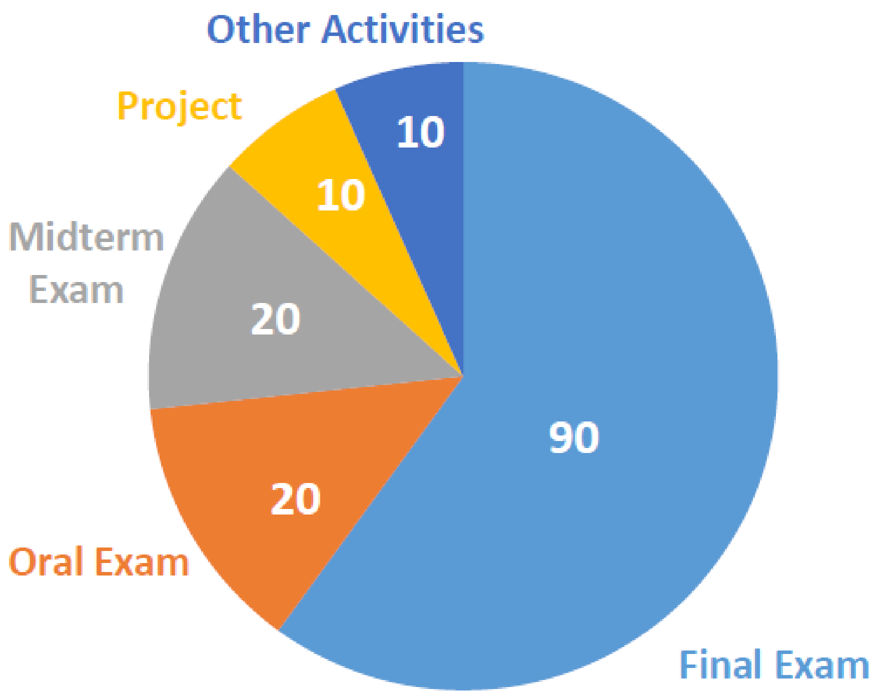
1. Measurement Errors and Measurement Characteristics
2. Electromechanical Instruments:
   - Permanent Magnet Moving Coil (PMMC).
   - DC Voltmeter, DC Ammeter and Ohmmeter.
   - AC Voltmeter, AC Ammeter.
3. Digital Type Multimeter:
   - Digital Voltmeter.
   - Digital Frequency Meter.
4. Sensors and Transducers: (To sense physical quantities)
   - Position and Displacement Sensors.
   - Force Sensors
   - Temperature Sensors

# Textbooks and References:

1. **Electronic Instrumentation and Measurements,** David A. Bell.
2. **Mechatronics: Electronic Control Systems in Mechanical Engineering,** W. Bolton.

# Course Evaluation:

- Total score: 150



# 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** |

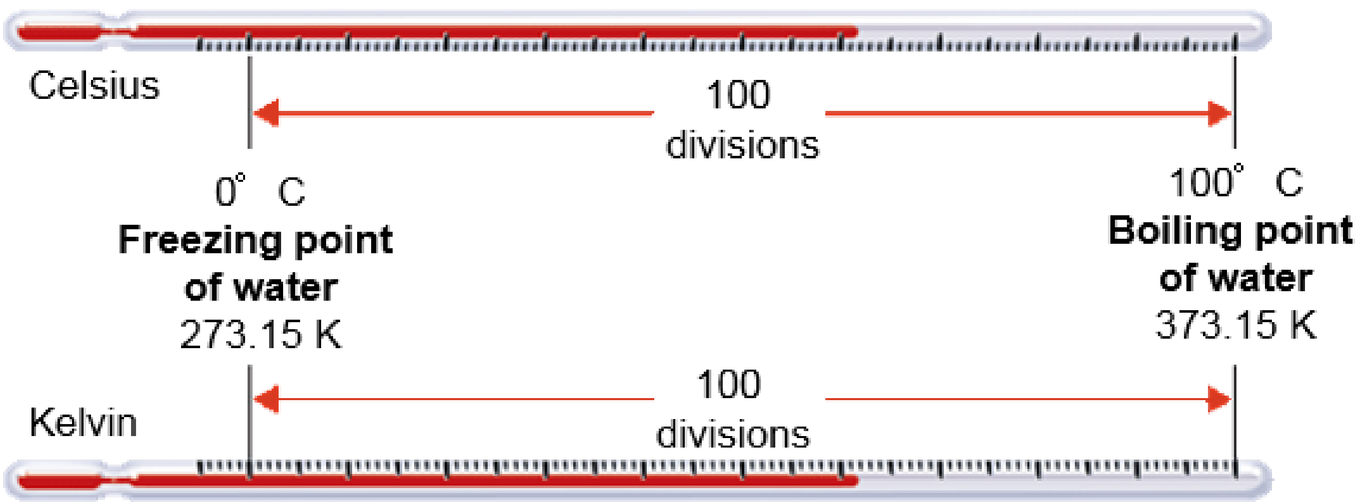
# 1.3 SI Electrical units:

- 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 | $\xi$ | 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 | $\Phi$ | 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 °C = K – 273 $°C = \frac{°F - 32}{1.8}$

# Chapter 2: Measurement Errors

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

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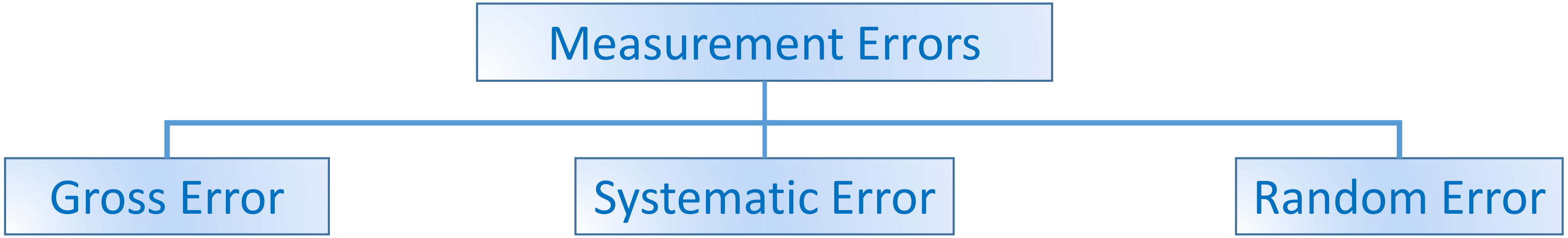
# Introduction:

- No electronic component or instrument **is perfectly accurate;** all have some error or inaccuracy.
- These errors are introduces 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 considered while performing measurement, where these errors could combine to create larger error.

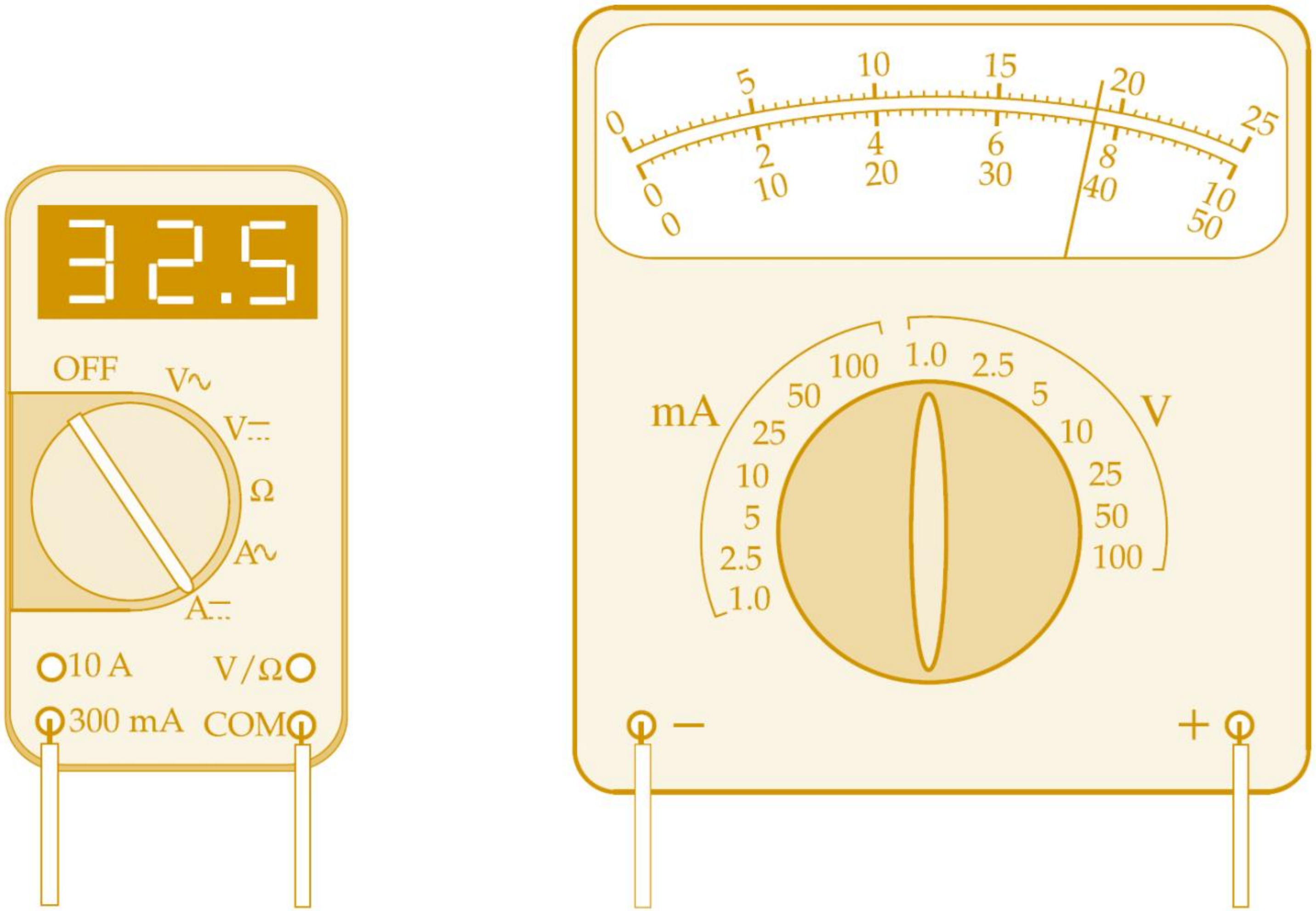
# 2.1 Measurement Errors types:

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).<br>• A wrong scale may be chosen in analog instruments.<br>• Transpose of the readings while recording. (24.9 mV instead of 29.4 mV). |




(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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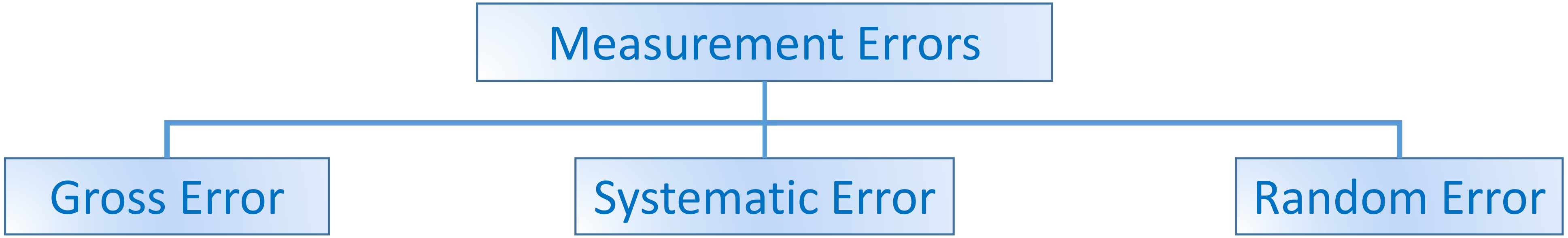


| Systematic Error |
| --- |
| Errors due to **problems with instruments.** |

- **Instrument Errors:** May be due to incorrect device calibration.
- **Environmental Errors:** Change in environmental conditions may change some of device parameters.
- **Observational Errors:** Errors introduced by the observer as the parallax error.

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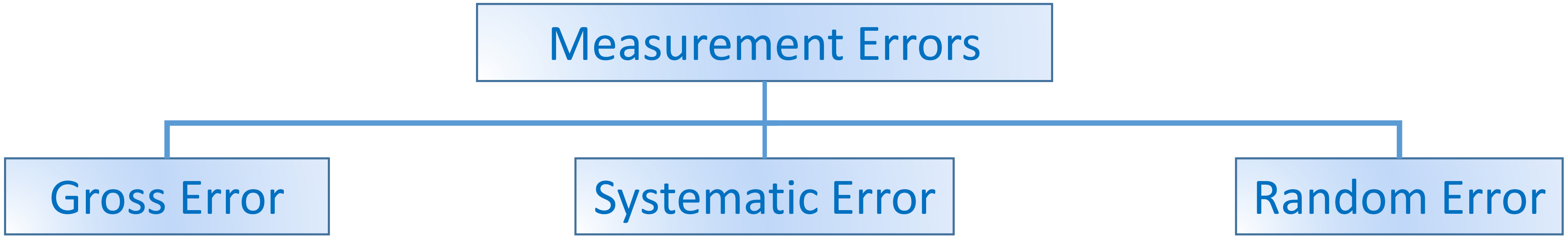


| Random Error |
| --- |
| Errors due to **unknown factors.** |

- 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.
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# 2.2 Absolute and Relative Errors:

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

**Absolute Error ($\Delta e$)**

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 $\Delta e$ 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

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

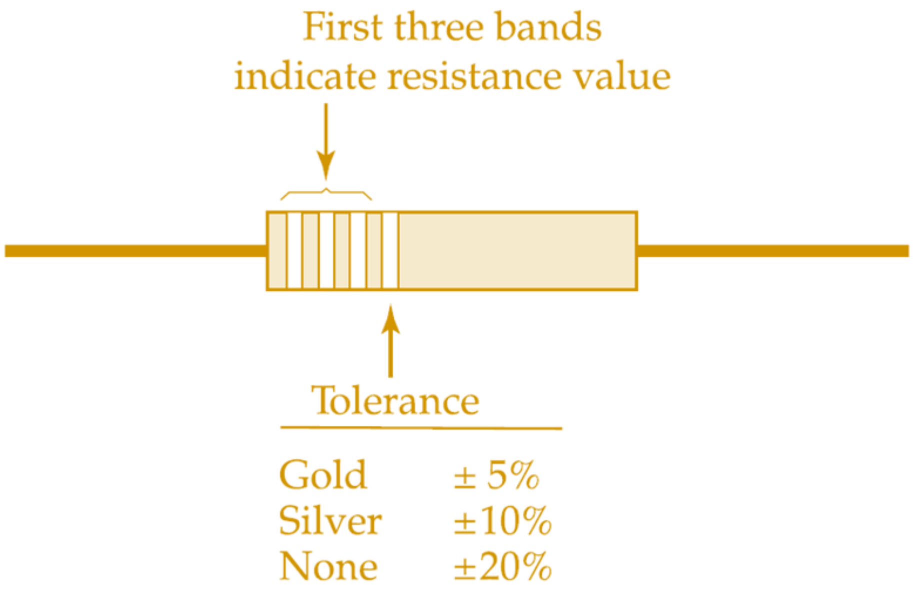


**Figure 2-2** The relative error in a measured or specified quantity is expressed as a percentage of the quantity. The absolute error is determined by converting the relative error into an absolute quantity.

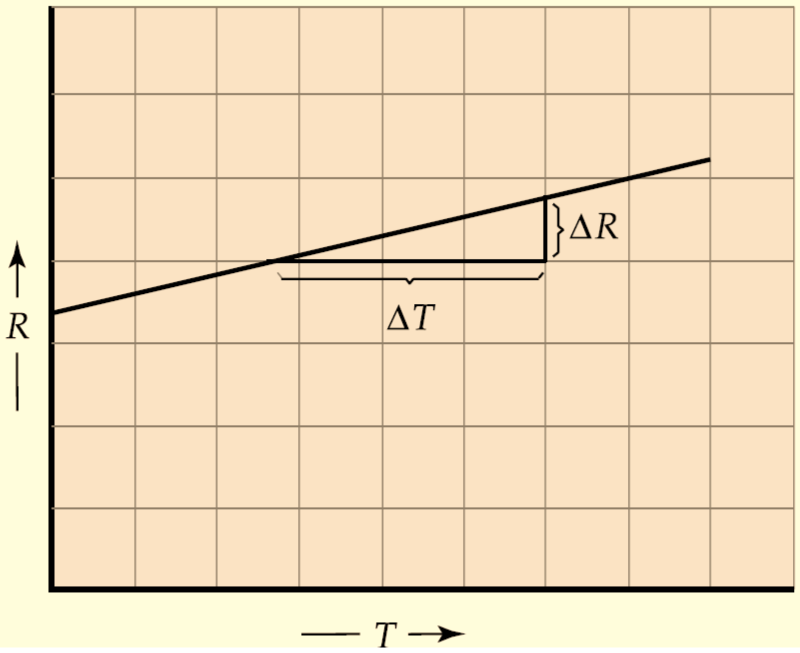


**Figure 2-3** Instead of percentages, errors can be expressed in parts per million (ppm) relative to the total quantity. Resistance change with temperature increase is usually stated in ppm/°C.

End of Lecture

Best Wishes