Mechatronic Instrumentations

001.0

Introduction

Dr Ezideen A Hasso

Measurements

Measurement: is the art and science of determining the properties of an object. These properties could weight, length, temperature, viscosity, pH, current and voltage, etc.

Measurements helps us to quantify (numbers) properties of different object and gives us a mean to assign proper units and figures and to these quantities.

Whatever exists in nature, it exists in certain amount, and the measurement can provide, to a degree, the amount of it.

- Measurements can also be defined as the process of converting known phenomenas into meaningful numbers.
- The tool that perform this process is called measuring instrument, measuring device or measuring equipment.
- e. g., AVO meter, stopwatch, pH meter, thermometer, ….

- Measuring devices usually provide two different entities: **1.** Number (representing the quantity), and **2.** Unit (of measurement)

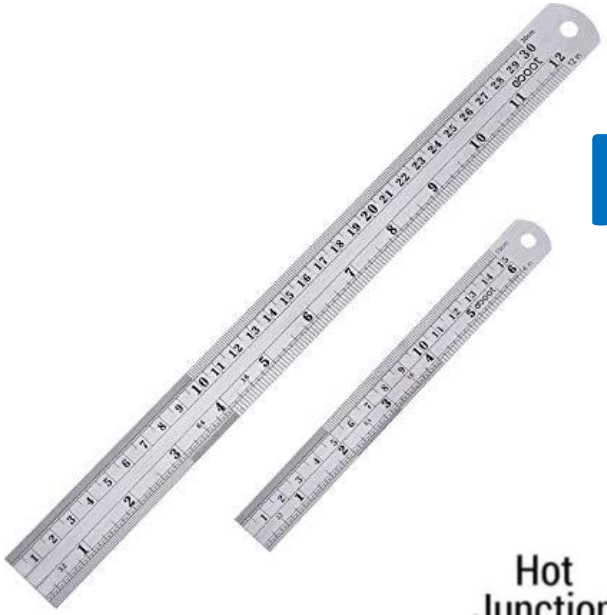
Pre-defined Entity and Measurand

- Measurement is achieved by the **comparison** of the measurand to a predefined standard entity

Measurement Techniques

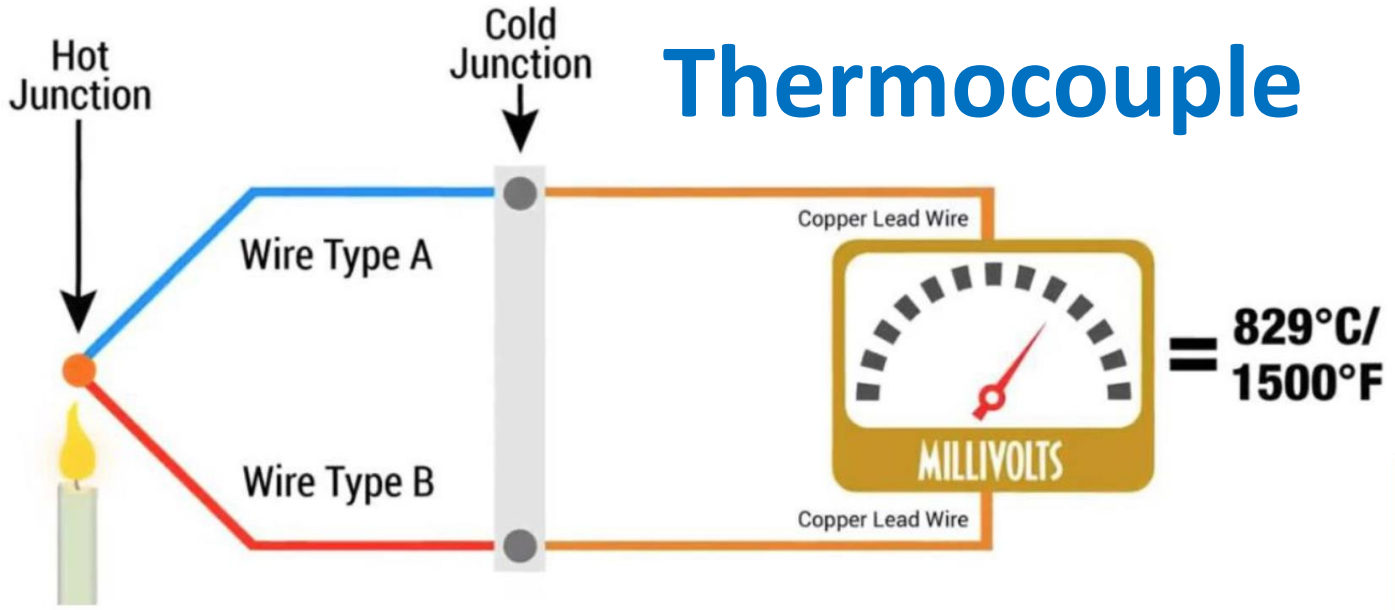
- In Measurement there are, mainly, two Techniques:
- **Direct Method** (the result represents the measurand)
- **Indirect method** (the result doesn't represent the measurand and further processing is required to achieve the final result-**signal processing**)

Direct and indirect measurements



Ruler

Thermocouple



Measurement System Comprises:

- Transducers
- Sensors
- Signal processing devices
- Actuators

Transducer

Transducer is defined as a substance or a device that converts (or transfers) an input energy into a different output energy. Because of this broad definition, transducers come in many varieties converting many different types of energy. Following are different types of transducers.

Examples of Transducers:

Electromechanical Transducers

- ✓ (Some are also called actuators)
- ✓ Strain gauge – Converts the deformation (strain) of an object into electrical resistance Galvanometer – Converts the electric current of a coil in a magnetic field into movement (defection)
- ✓ Generators – Converts mechanical energy (motion) into electrical energy
- ✓ Motor – Converts electrical energy into mechanical energy

Photoelectric Transducers

- ✓ **Cathode ray tube (CRT) –Converts electrical signals into light energy for a visual output**
- ✓ **Light bulb –Converts electrical energy into visible light and heat (explained in next section)**
- ✓ **Laser diode – Converts electrical energy into light energy**
- ✓ **Photodiode - Converts light energy into electrical energy**

Thermoelectric Transducers:

Thermocouple – Converts heat energy into electrical energy

Temperature sensitive resistor (Thermistor) – a variable resistor affected by temperature changes (heat energy to electrical energy)

Other types of Transducers:

Geiger-Müller tube – Converts radioactive energy into electrical energy

Quartz Crystal (Piezoelectric) – Converts mechanical stress into electricity (electrical energy)

Pitot Tube converts pressure into displacement

Pyranometer measure the solar radiation flux density (W/m^2) from the hemisphere above within a wavelength range 0.3 to 3 µm.

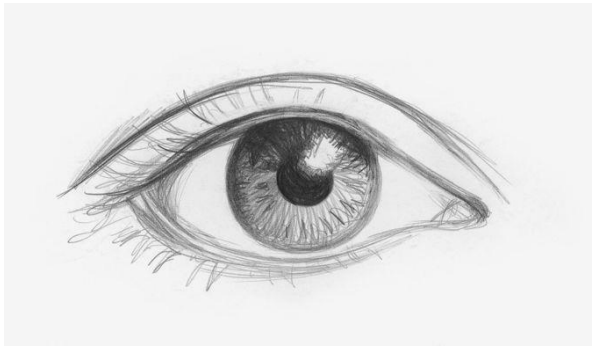
Other types of Transducers: (continue)

Anemometer this is an air velocity measuring device. The core of this instrument is simply a Tachometer which converts angular velocity to voltage.

Sensors

- Sensors detect:
  1. the presence of energy;
  2. the changes in energy; or
  3. the transfer of energy
- Sensors detect by receiving a signal from a device such as a transducer, then responding to that signal by converting it into an output that can be easily read and understood.
- Typically, in industries, sensors convert a recognized signal into an electrical – analog or digital – output that is readable

The Five Human Sensors



Basic Concepts of Actuators

An actuator is a device that actuates or moves an object within a system. More specifically, an actuator is a device that coverts energy into motion or mechanical energy. Therefore, an actuator is a specific type of a transducer

Thermal Actuators

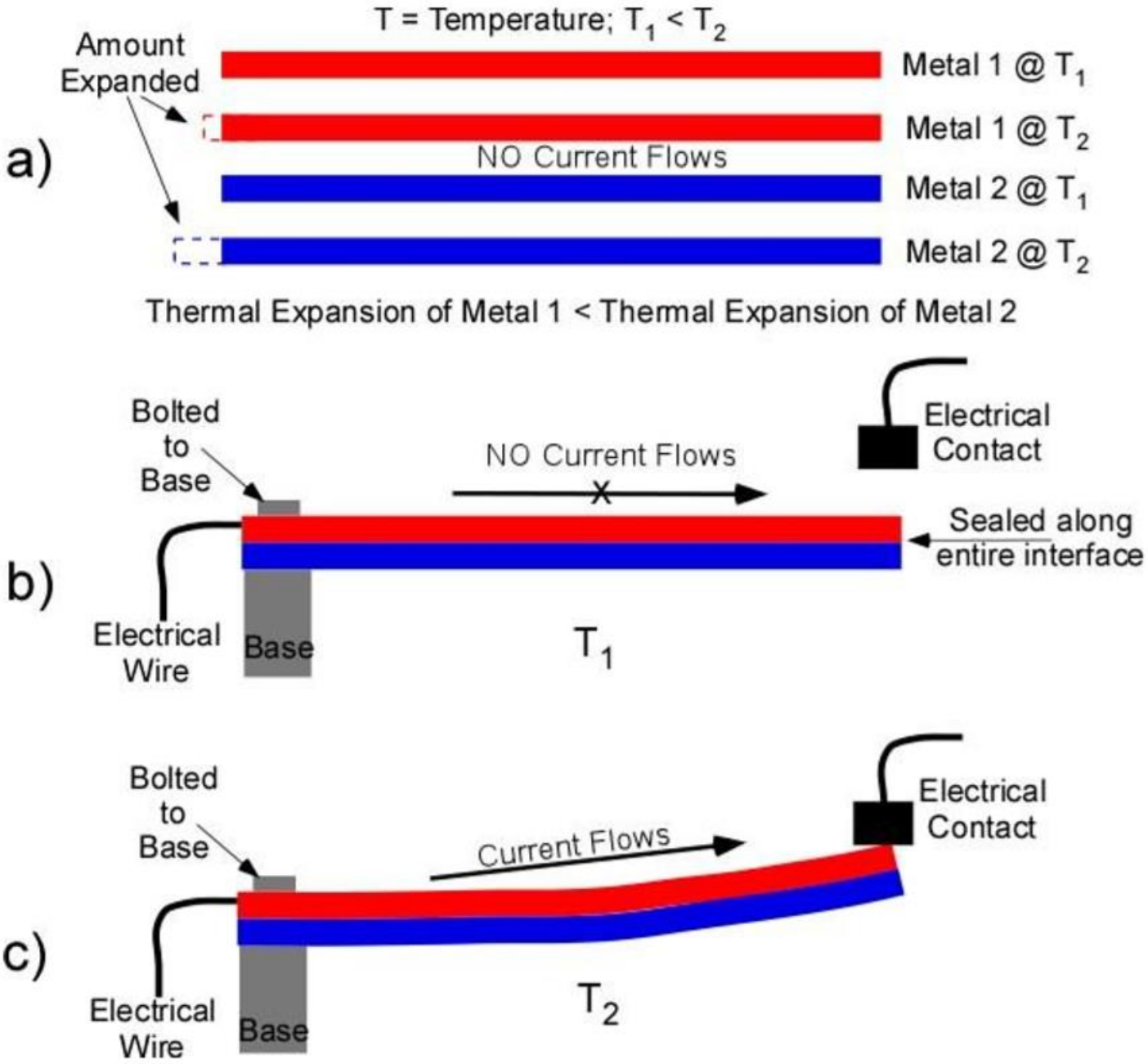
One type of thermal actuator is a bimetallic strip. This device directly converts thermal energy into motion. This is accomplished by utilizing an effect called thermal expansion.

Thermal expansion is the manifestation of a change in thermal energy in a material. When a material is heated, the average distance between atoms (or molecules) increases. The amount of distance differs for different types of material. This microscopic increase in distance is unperceivable to the human eye. However, because of the huge numbers of atoms (or molecules) in a piece of material, the material expands considerably and, at times, is noticeable to the human eye.

- Consider a piece of steel 25 meters long. If the temperature of the steel increases by 36°C, (the difference between a cold winter day and a hot summer day), that piece of steel lengthens approximately 12 cm. This change in length is the thermal linear expansion. It is calculated by using the following formula:

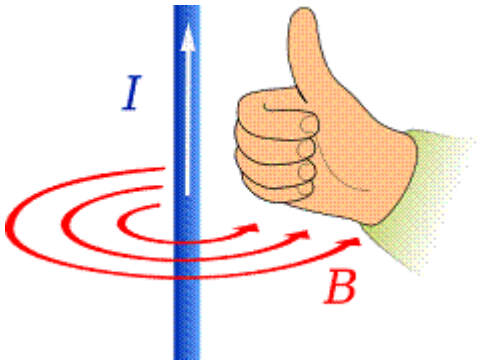
$$\Delta L = a\, Lo\, \Delta T$$

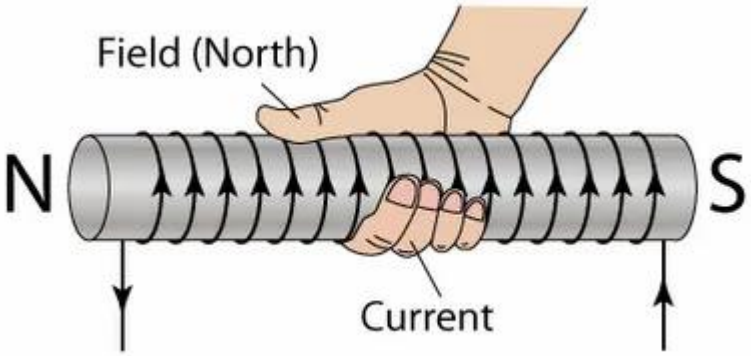
- Where, **ΔL** is the change in length, **a** is the coefficient of linear expansion, **Lo** is the original length, and **ΔT** is the change in temperature in Celsius. If we are considering steel, the coefficient of linear expansion is 1.3×10^{-5} , the original length is 25 meters, and of course the change of temperature is 36°C. This results in an expansion of .12 m or 12 cm.


T = Temperature; $T_1 < T_2$
Amount Expanded
Metal 1 @ T_1
Metal 1 @ T_2
NO Current Flows
Metal 2 @ T_1
Metal 2 @ T_2
a)
Thermal Expansion of Metal 1 < Thermal Expansion of Metal 2
Bolted to Base
NO Current Flows
Electrical Contact
Sealed along entire interface
b)
Electrical Wire
Base
T_1
Bolted to Base
Current Flows
Electrical Contact
c)
Electrical Wire
Base
T_2

Electric Actuator

Fleming's Hand Rule





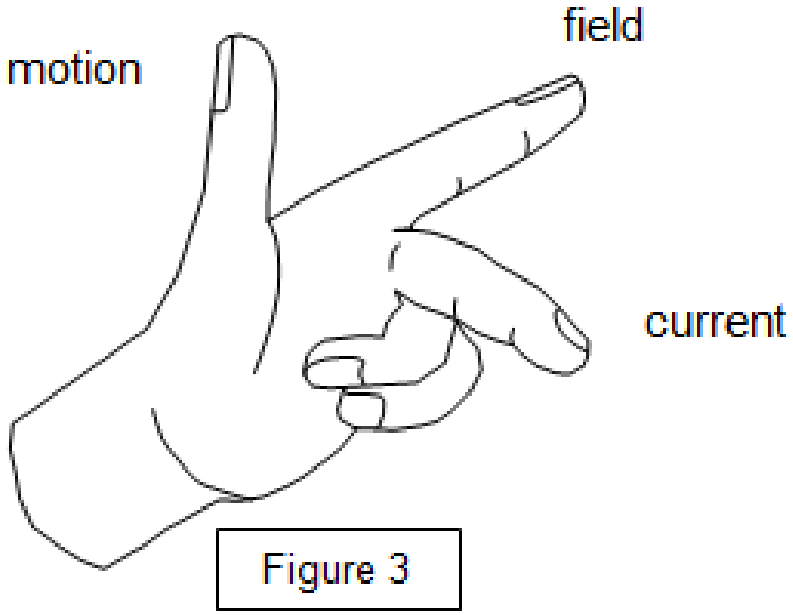


Figure 3

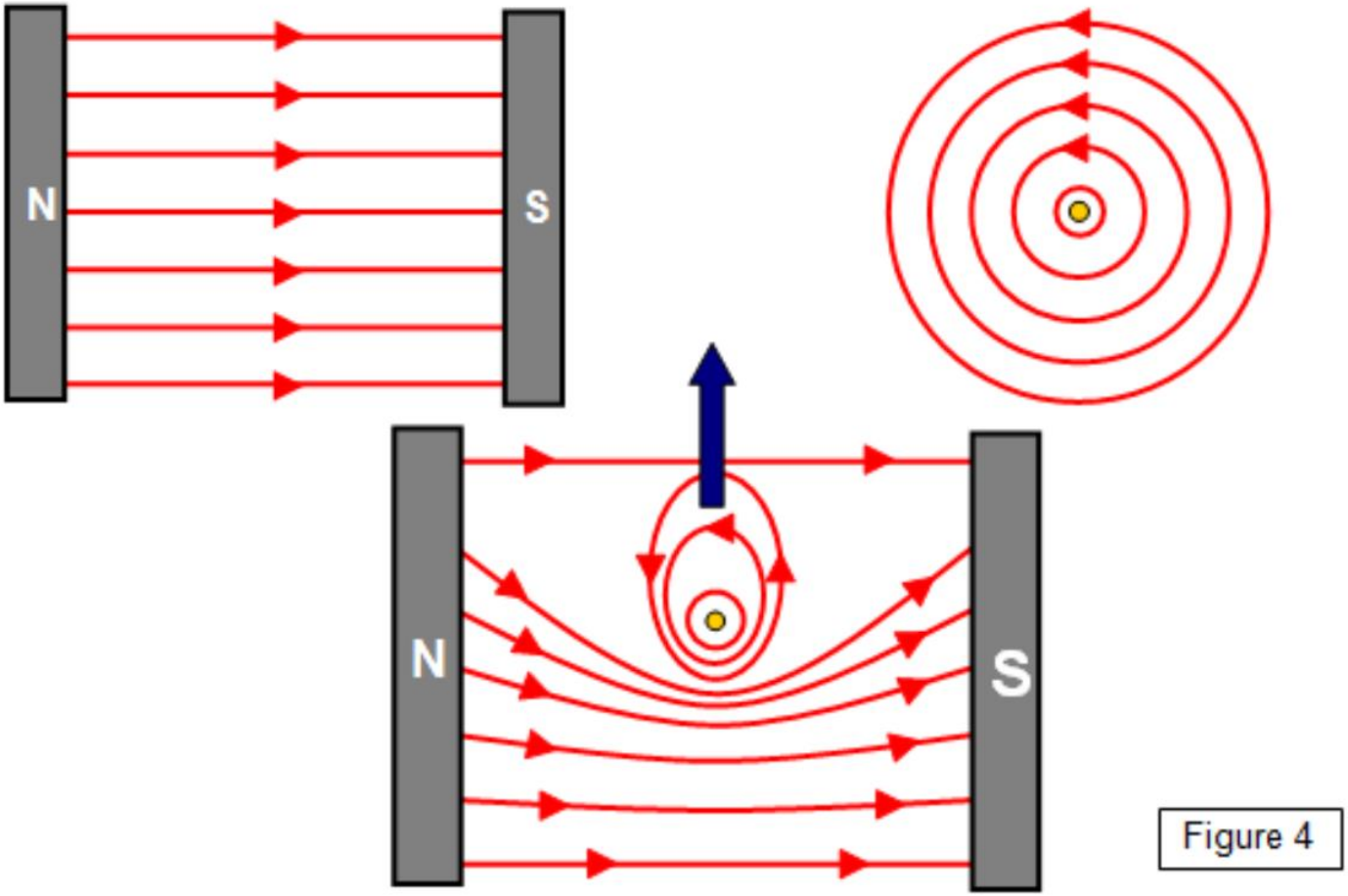


Figure 4

Mechanical Actuator

Mechanical actuators convert a mechanical input (usually rotary) into linear motion. A common example of a mechanical actuator is a screw jack. The figure below shows a screw jack in operation. Rotation of the screw causes the legs of the jack to move apart or move together. Inspecting the motion of the top point of the jack, this mechanical rotational input is clearly converted into linear mechanical motion.