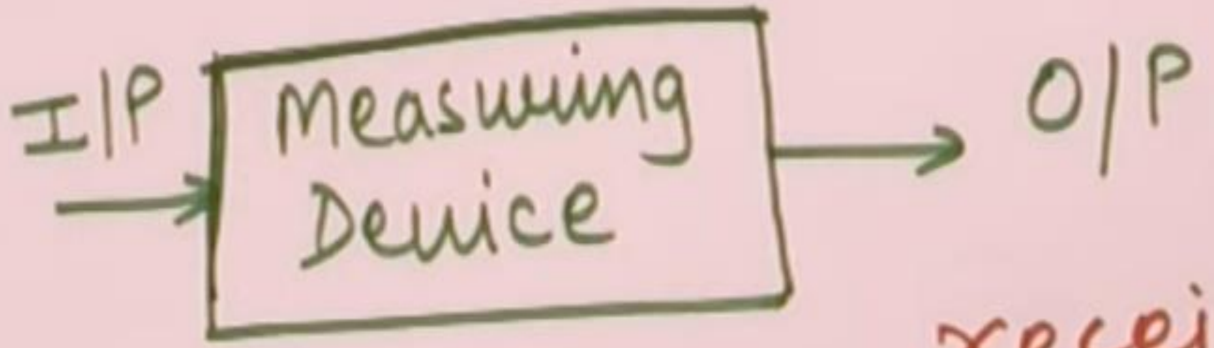
What is a Transducer?

Non-electrical quantity.



receives the measurand

1) Input Device
2) Signal Conditioning or Processing device
   filter, amplify, attenuate, modulate
3) Output Device.

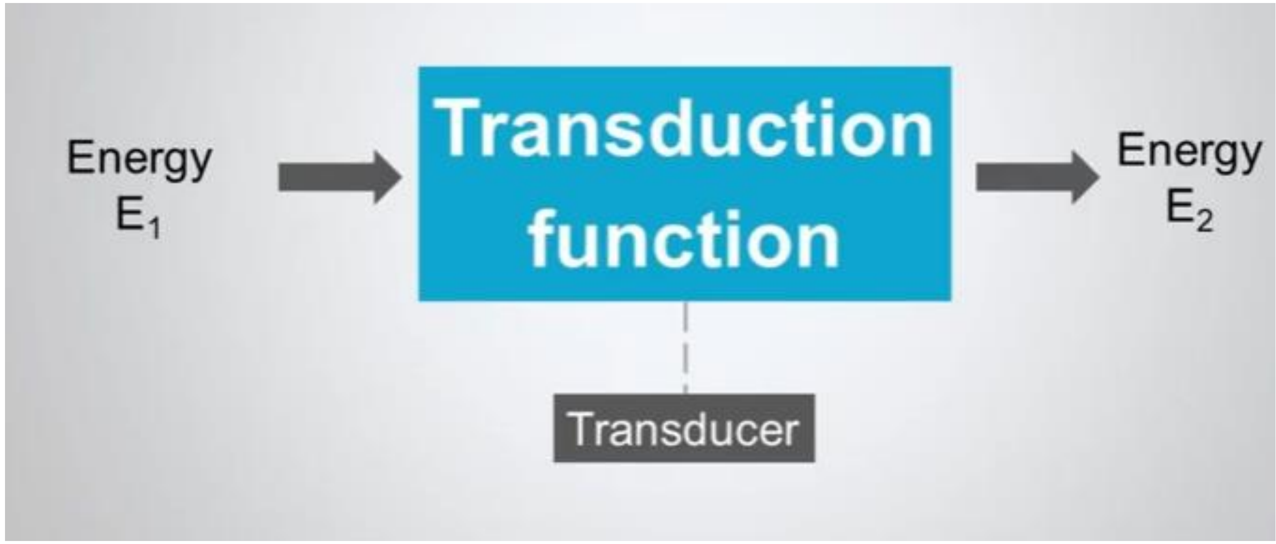
Results

* "TRANSDUCER" is a device which converts non-electrical quantity into an electrical quantity.

energy

energy

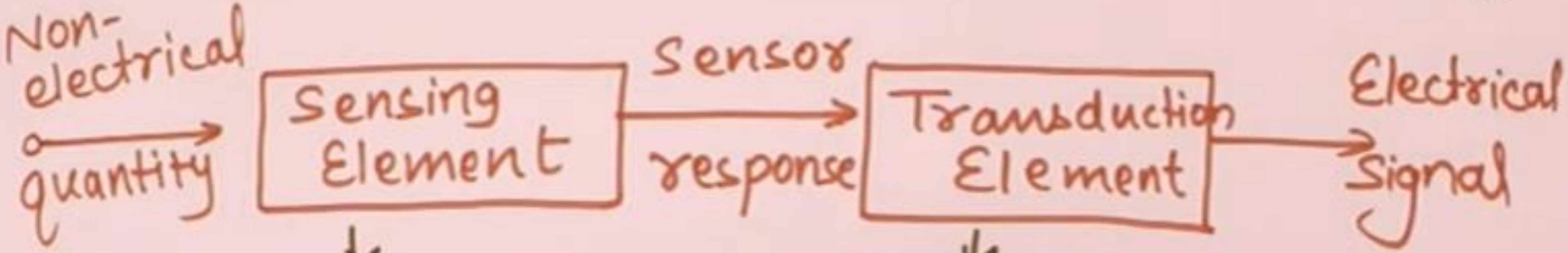
* Transducer converts one form of energy into another form.



* Transducers provide an output signal when stimulated by a mechanical or a non-mechanical input.

Transducer consists of basically two components :→

1) Sensing element
2) Transduction element.



Physical quantity or its rate of change is sensed and responded

convert the non-electrical signal into its proportional electrical signal.

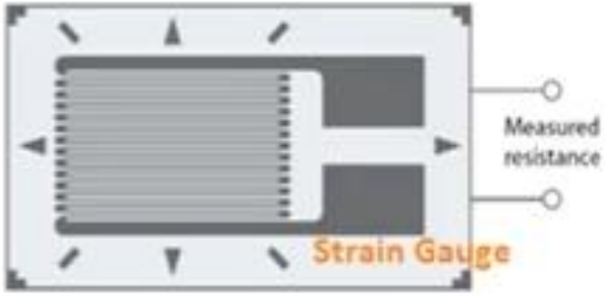
In measurement system, information processing is performed by electrical signals, with the input or the output, being in

Electrical form	Non-electrical form
Voltage	Displacement
Current	Temperature
Resistance	Elasticity
Capacitance	Pressure
Inductance	Proximity

Application of Transducer

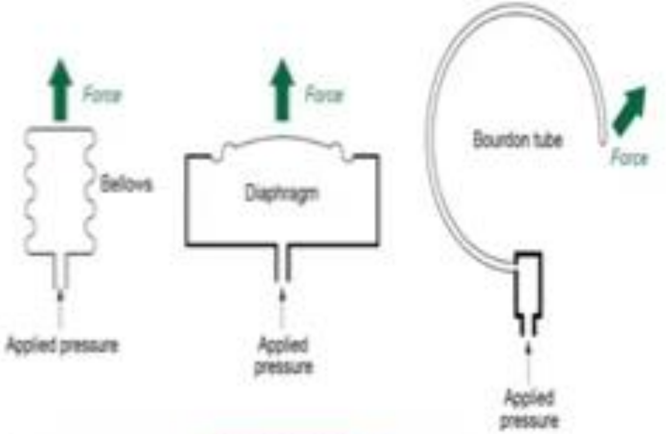
Sensor:

It is a device that converts from one form of physical quantity to a corresponding signal of different physical quantity.



Physical quantities like temperature, pressure, flow, level, humidity, acceleration, velocity, position, voltage, resistance, capacitance, current, radiation etc.

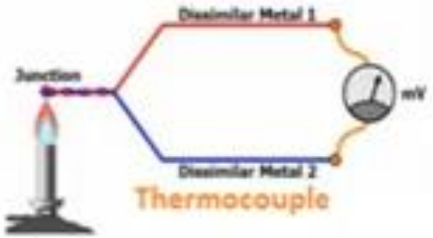
Ex: Bellows – convert pressure to linear displacement,

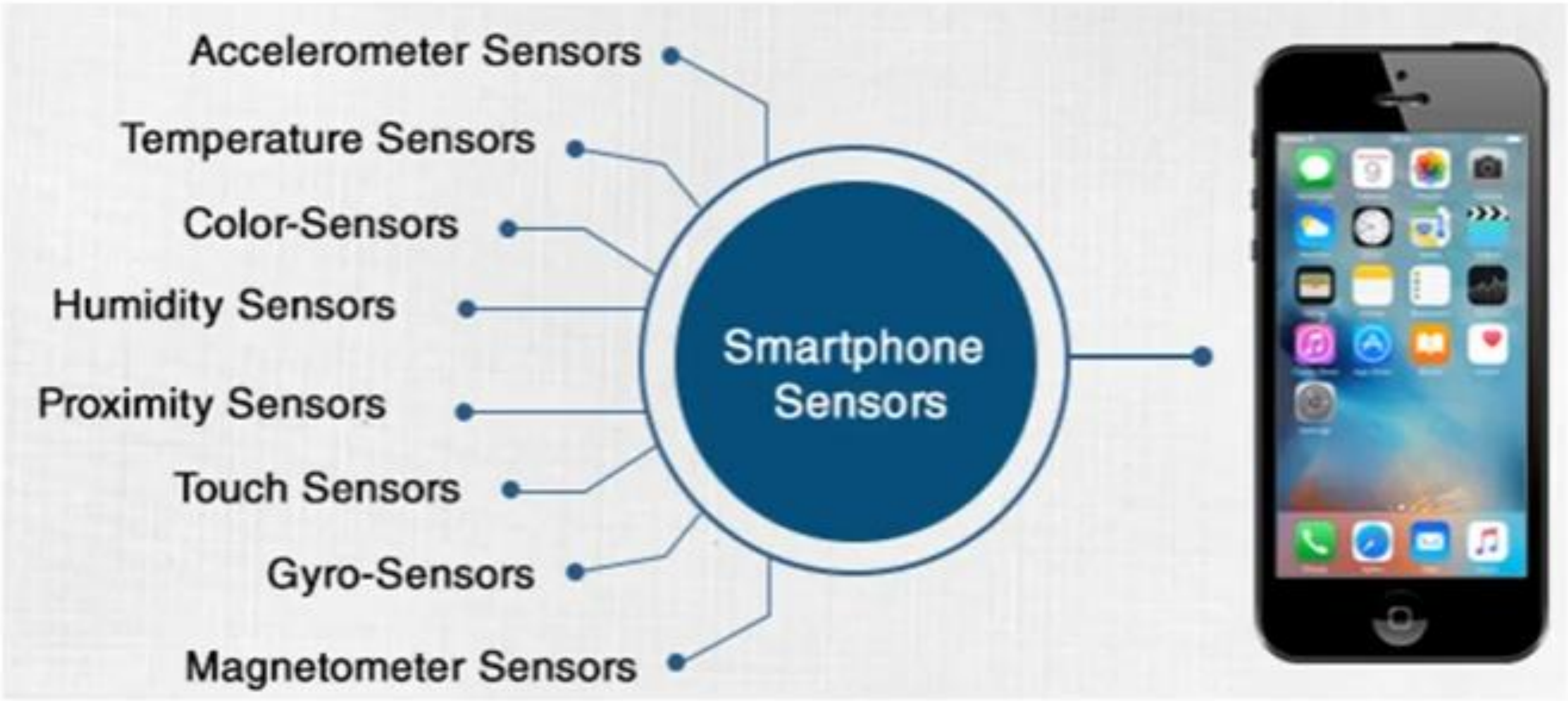


Bourdan tube – convert pressure to angular displacement

Strain gauge – convert strain into resistance

Thermocouple – Converts temperature to micro volt (Thermal energy is converted to thermal energy)

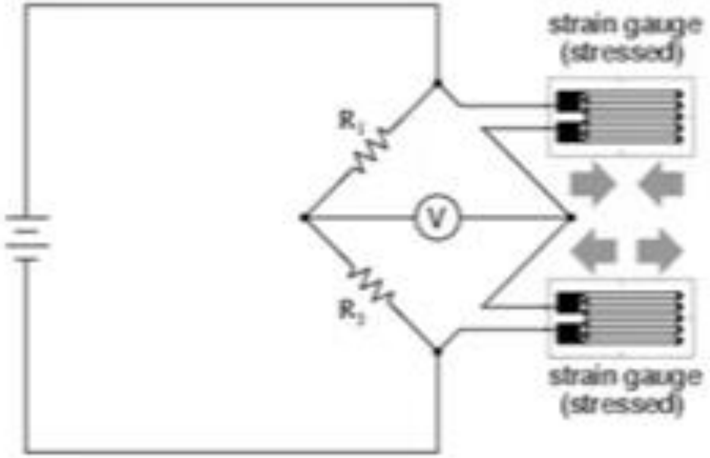



Accelerometer Sensors
Temperature Sensors
Color-Sensors
Humidity Sensors
Proximity Sensors
Touch Sensors
Gyro-Sensors
Magnetometer Sensors
Smartphone Sensors

Transducer:

- A transducer is the sensing element that converts any physical quantity into an electrical signal.
- Analog electrical signal may be mV, V and mA signal.
- Sensor + signal conditioning circuit (Strain gauge + wheat stone bridge) is known as transducer.

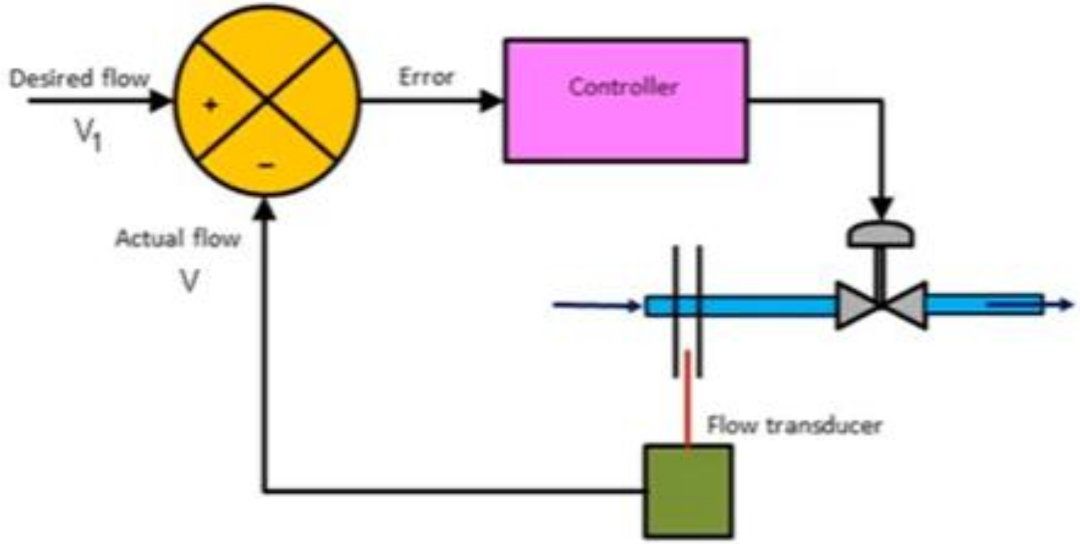
Half-bridge strain gauge circuit



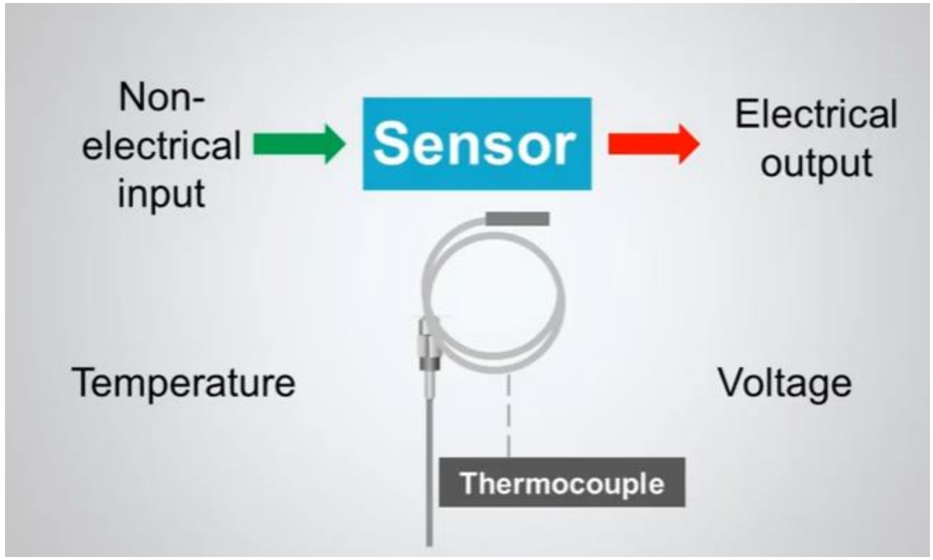
Actuator

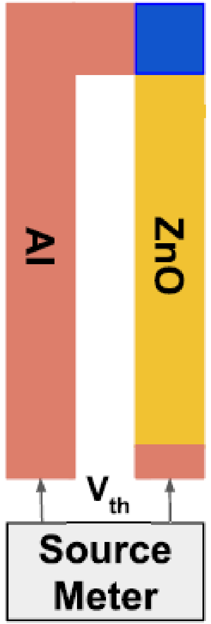
➢An actuator is a component of a machine/system that is responsible for controlling a mechanism or system, for example valve.

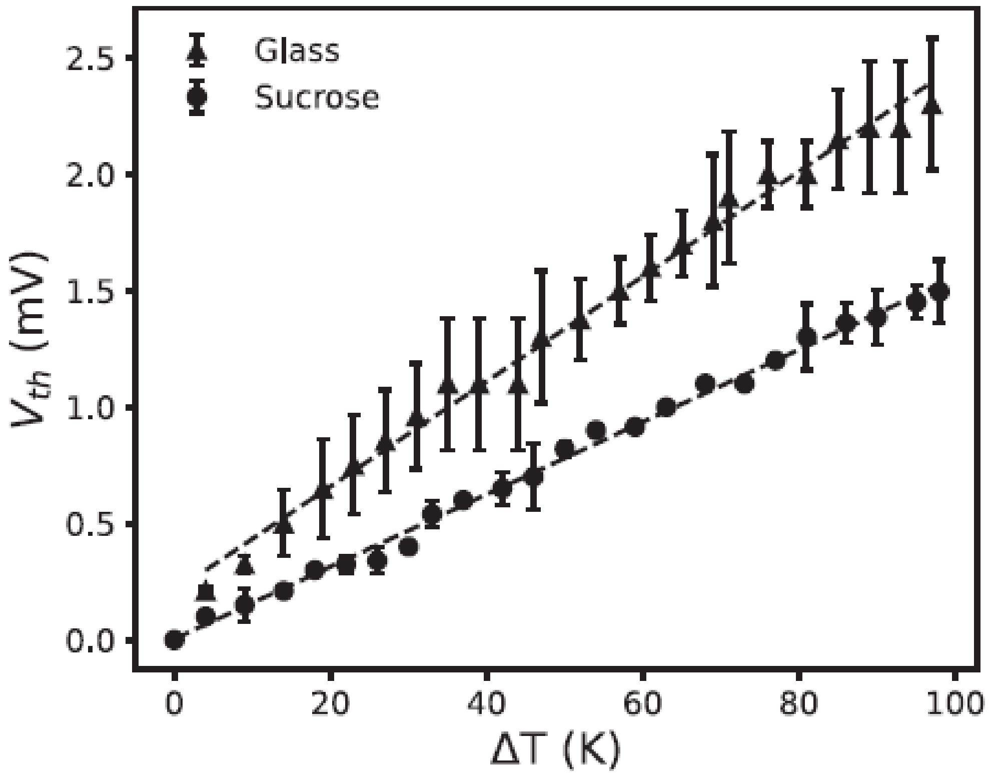
➢Actuator is also known as Final Control Element (FCE).

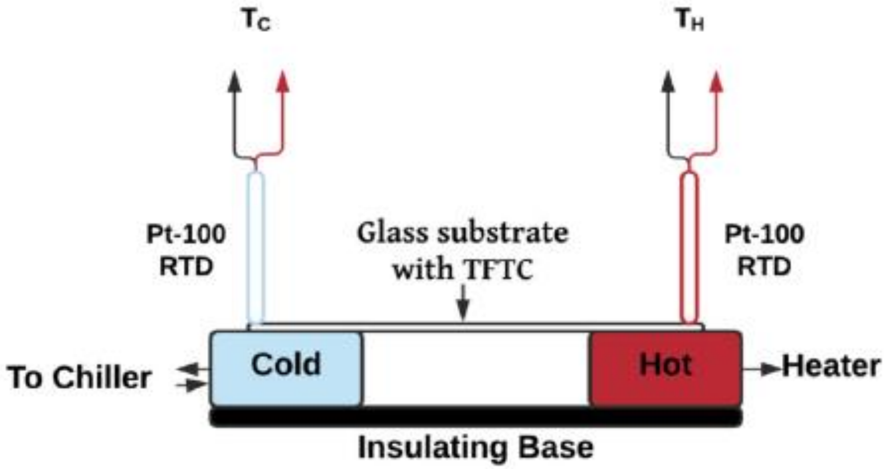


Thermocouple



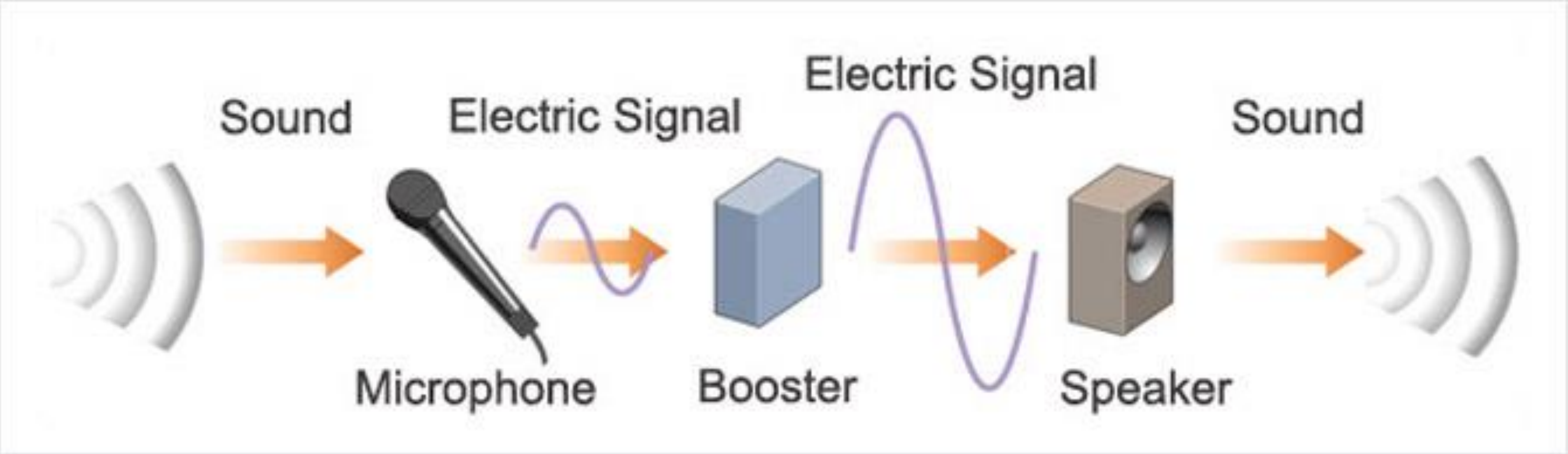


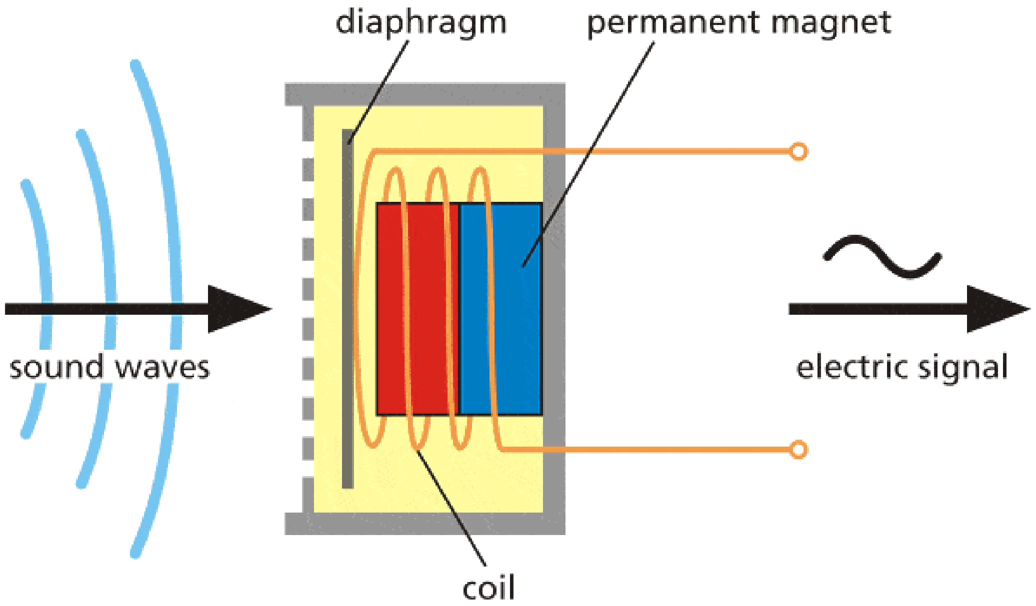


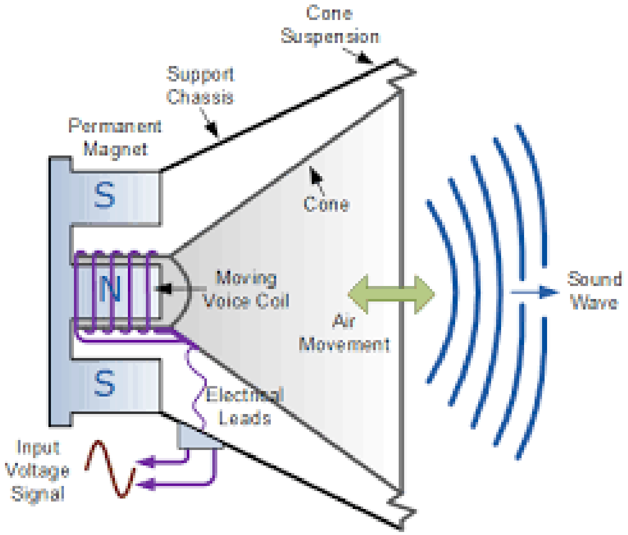


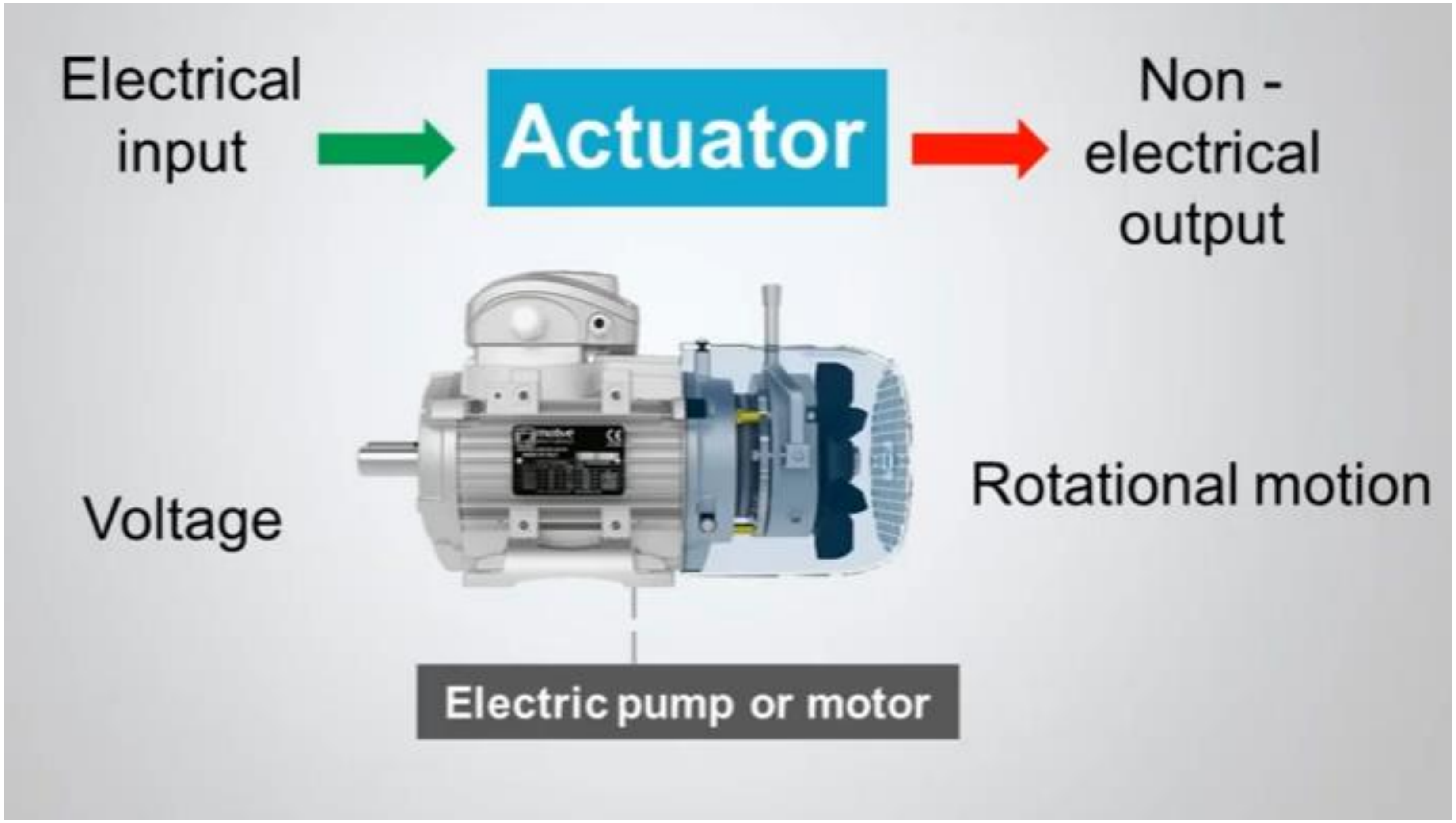
See back effect

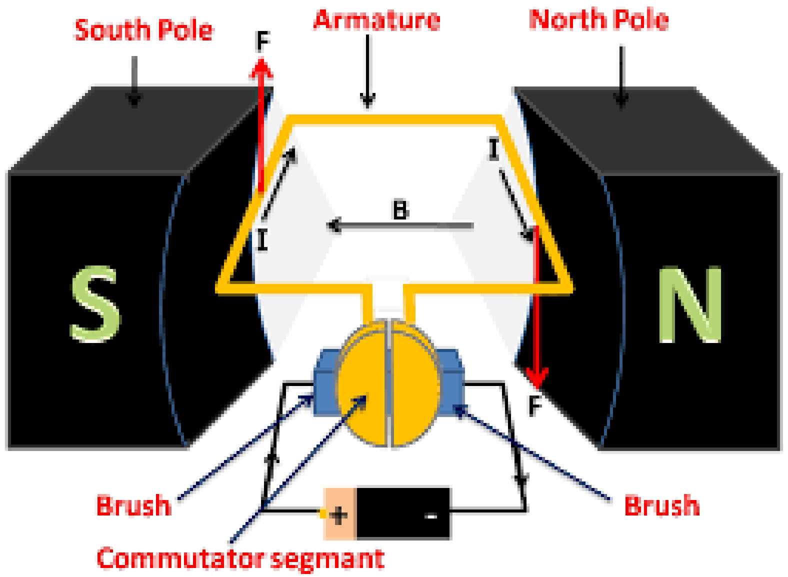

Sound waves
Electrical signal
Diaphragm's properties or characteristics


Sound
Electric Signal
Electric Signal
Sound
Microphone
Booster
Speaker

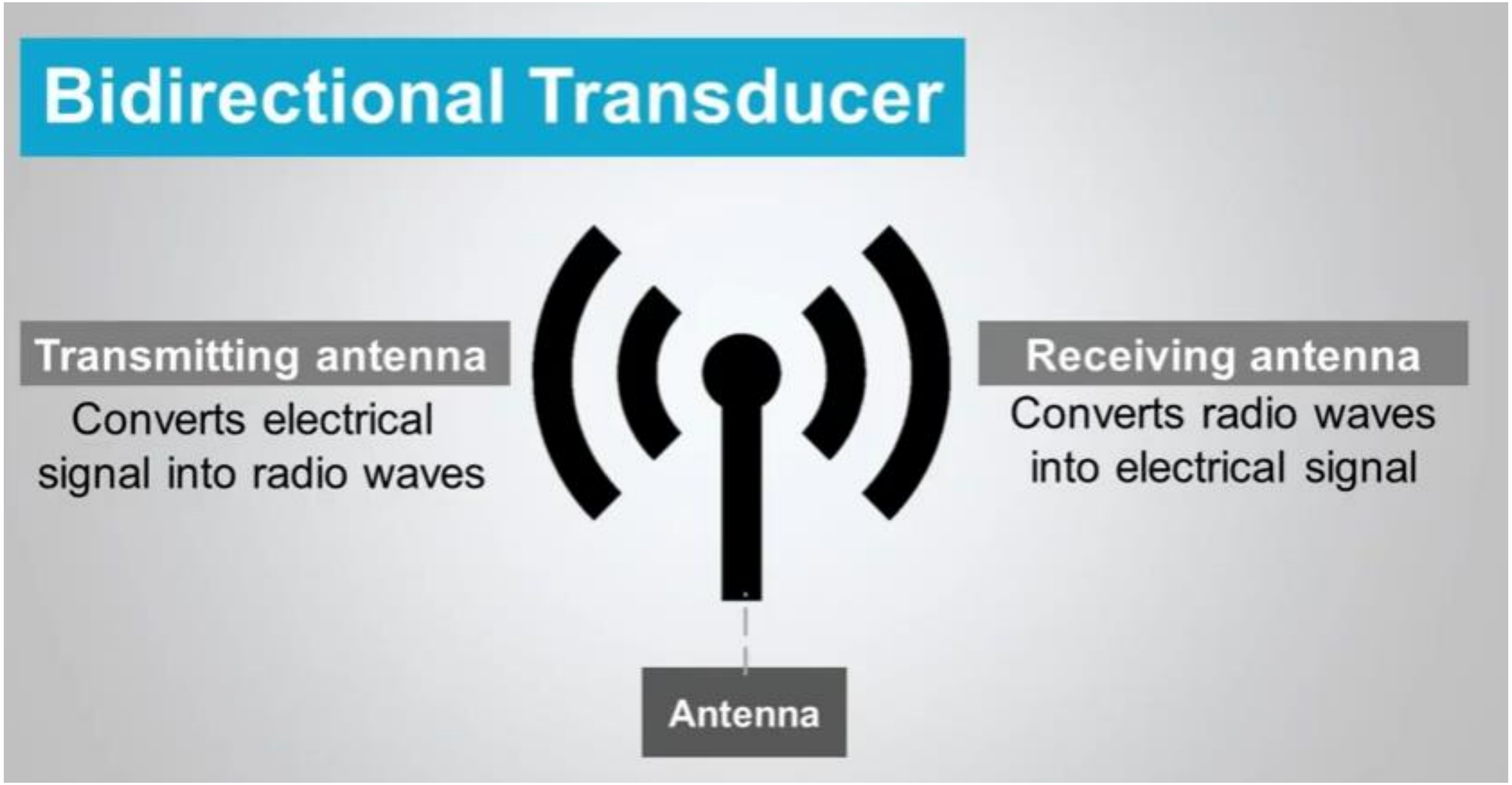

diaphragm
permanent magnet
sound waves
electric signal
coil

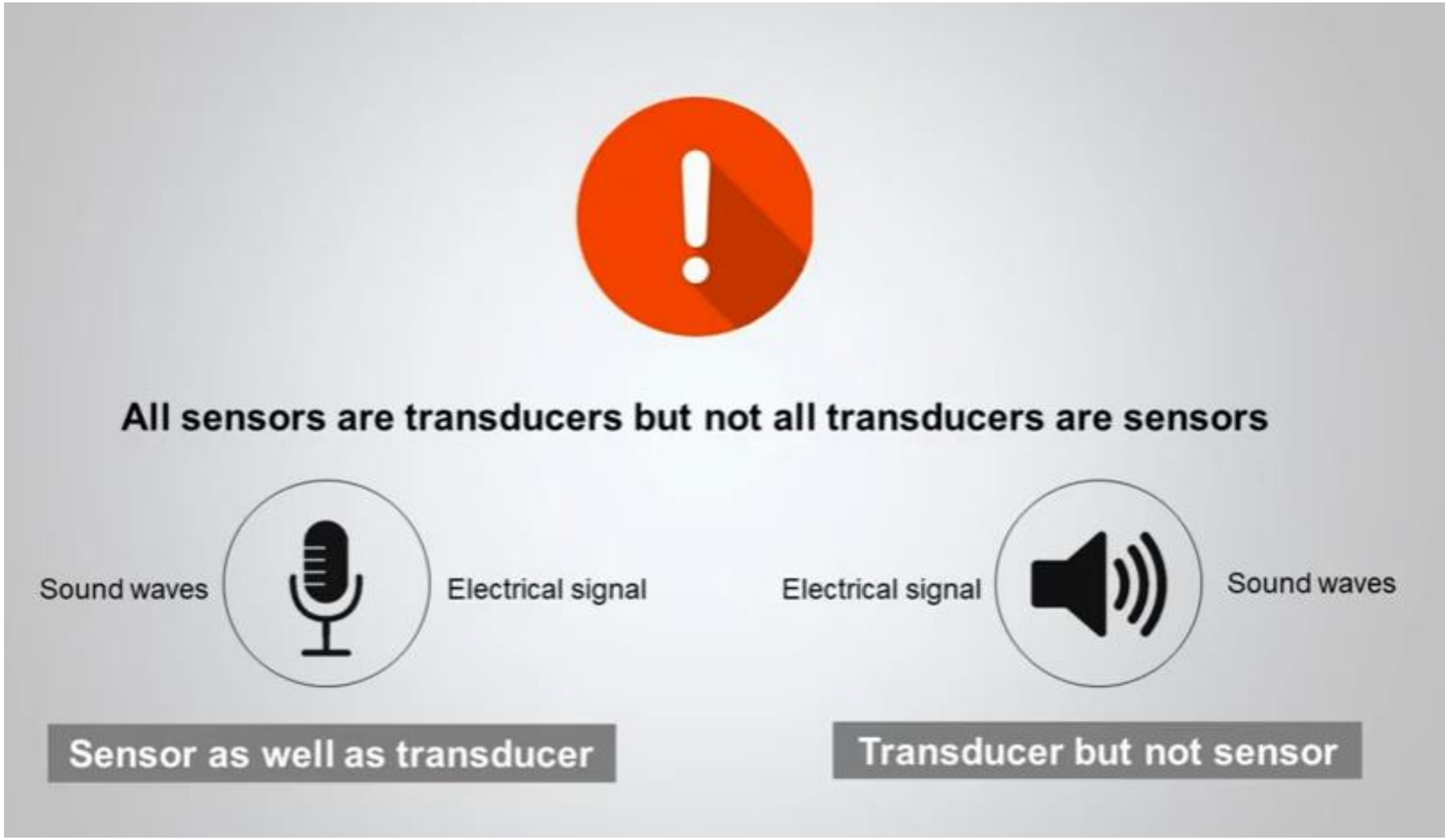

Cone
Suspension
Support
Chassis
Permanent
Magnet
S
Cone
N
Moving
Voice Coil
Air
Movement
Sound
Wave
S
Electrical
Leads
Input
Voltage
Signal

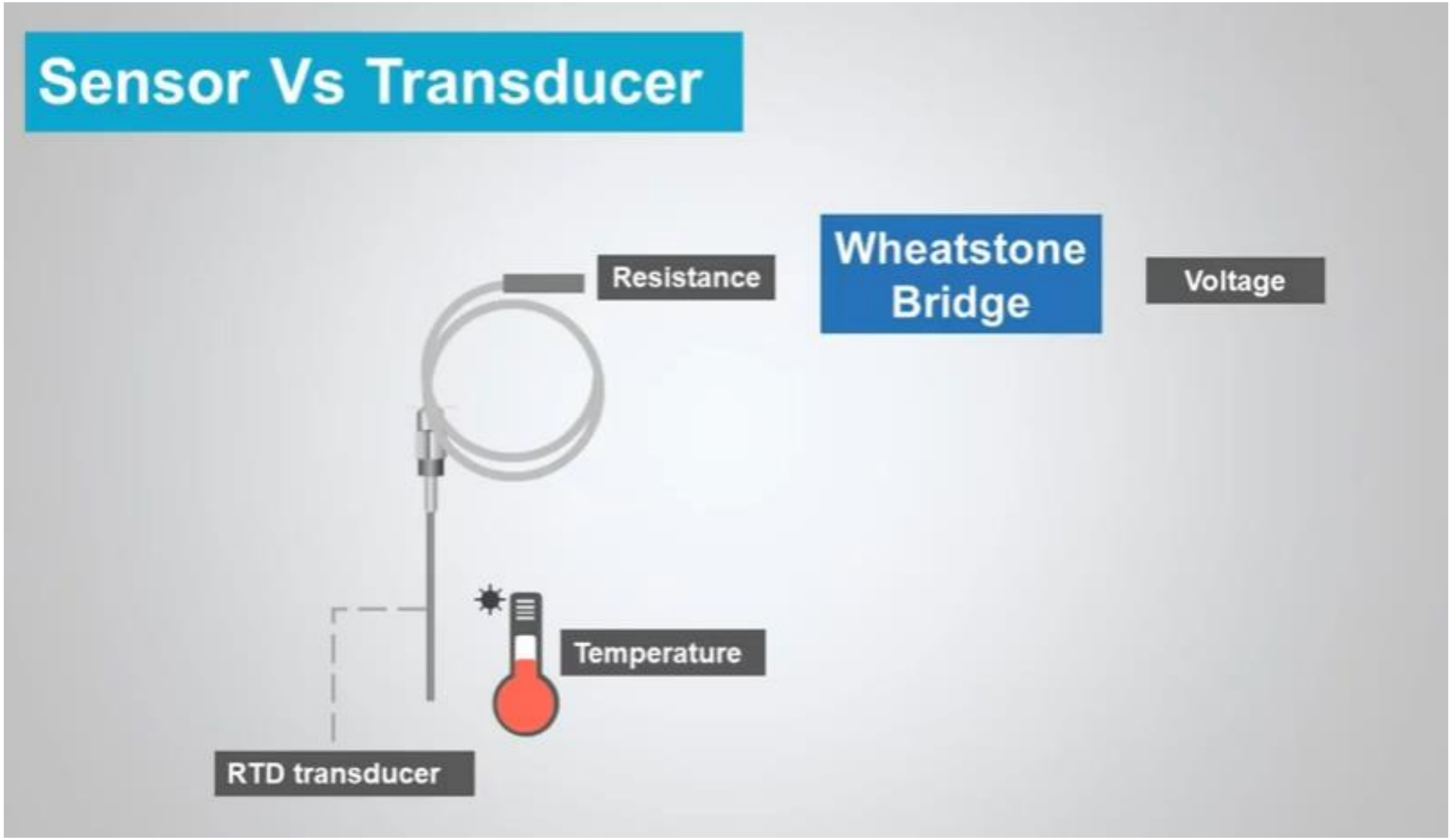

Electrical input
Actuator
Non - electrical output
Voltage
Rotational motion
Electric pump or motor

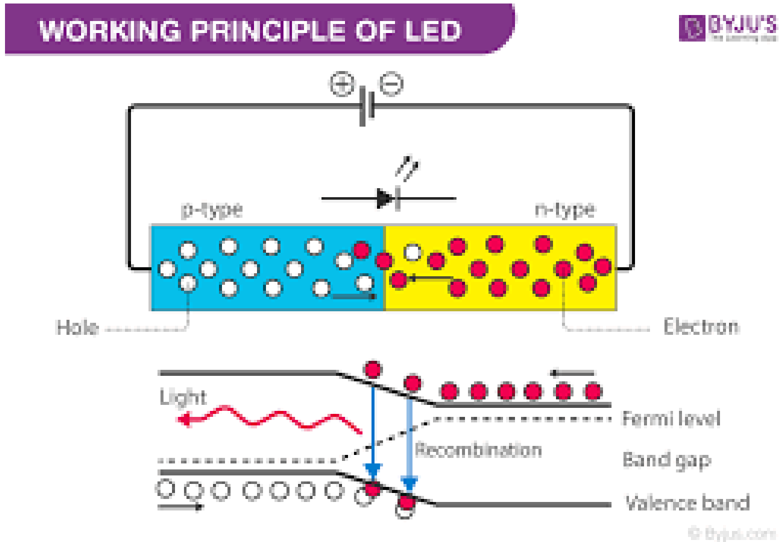

South Pole
F
Armature
North Pole
I
B
I
S
N
F
Brush
Brush
+
-
Commutator segmant





Bidirectional Transducer
Transmitting antenna
Converts electrical signal into radio waves
Receiving antenna
Converts radio waves into electrical signal
Antenna


All sensors are transducers but not all transducers are sensors
Sound waves
Electrical signal
Electrical signal
Sound waves
Sensor as well as transducer
Transducer but not sensor


Sensor Vs Transducer
Resistance
Wheatstone Bridge
Voltage
Temperature
RTD transducer


WORKING PRINCIPLE OF LED
BYJU'S
p-type
n-type
Hole
Electron
Light
Fermi level
Recombination
Band gap
Valence band

characteristics of Transducer

* 3 types of characteristics

1) Input Characteristics
   - Type of I/P and Operating Range
   - Loading Effects
2) Transfer Characteristics
   - Transfer Function
   - Error
   - Response of transducer to environmental influences
3) Output Characteristics
   - Type of O/P
   - O/P Impedanc
   - Useful R

Input Characteristics

1) Type of Input and Operating Range →

* The type of i/p can be any physical quantity.
* A physical quantity can be measured by number of transducers.
* Choice of a particular transducer that is selected for the purp
depends upon the useful range of i/p quantity.

upper limit → decided by the transducer capabilities.

Lower limit → determined by the transducer error or by the unavoidable noise originating in the transducer.

(2) Loading effects →

* Ideally a transducer should have no loading effects on the i/p quantity being measured.

* Magnitude of loading effect is expressed in terms of force, power or energy extracted from the quantity under measurement for working of transducer

* Transducer selected for a particular application should ideally extract no force, power or energy from the i/p quantity so that it can be measured accurately.

Transfer Characteristics

1) Transfer Function :-

Transfer function of a transducer defines a relationship between the input quantity and the output quantity.

T. F is $\Rightarrow$ $q_o = f(q_i)$

q_o → o/p of the transducer

q_i → i/p of the transducer

Sensitivity of a transducer :→

$$S = \frac{dq_o}{dq_i}$$

Scale factor :→ inverse of sensitivity

$$\Rightarrow \frac{1}{S} = \frac{dq_i}{dq_o}$$

② Error :→

Errors occur because transducers donot follow the i/P – o/P relationship given by →

$$q_o = f(q_i)$$

$q_i \longrightarrow q_o$

$\hookrightarrow q_o'$

$$\boxed{\varepsilon = q_o' - q_o}$$

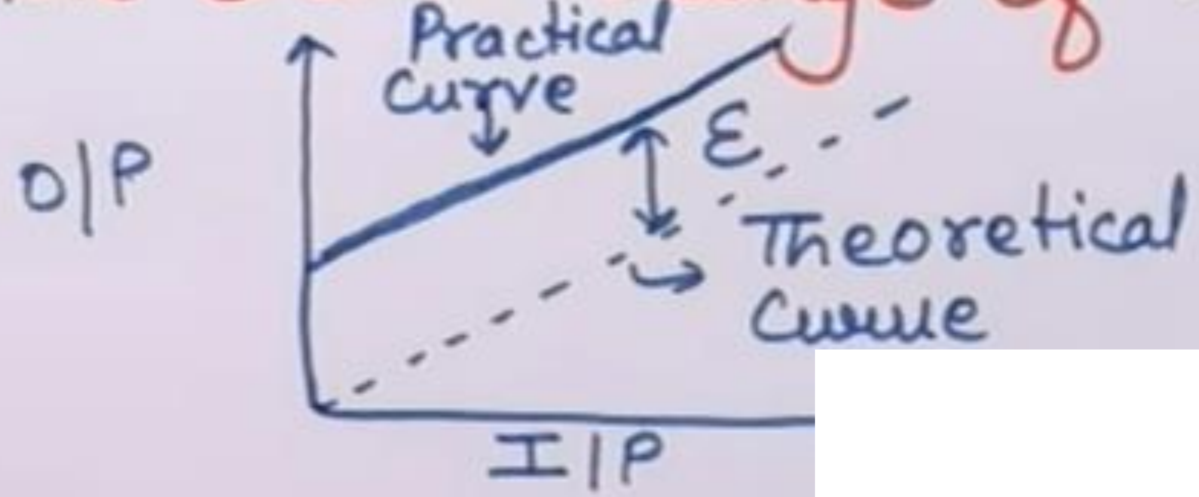
3 types of errors →

1) Scale error → Zero Error, Sensitivity error, Non-conformity, Hysteresis.

2) Dynamic error

3) Error on account of noise and drift.

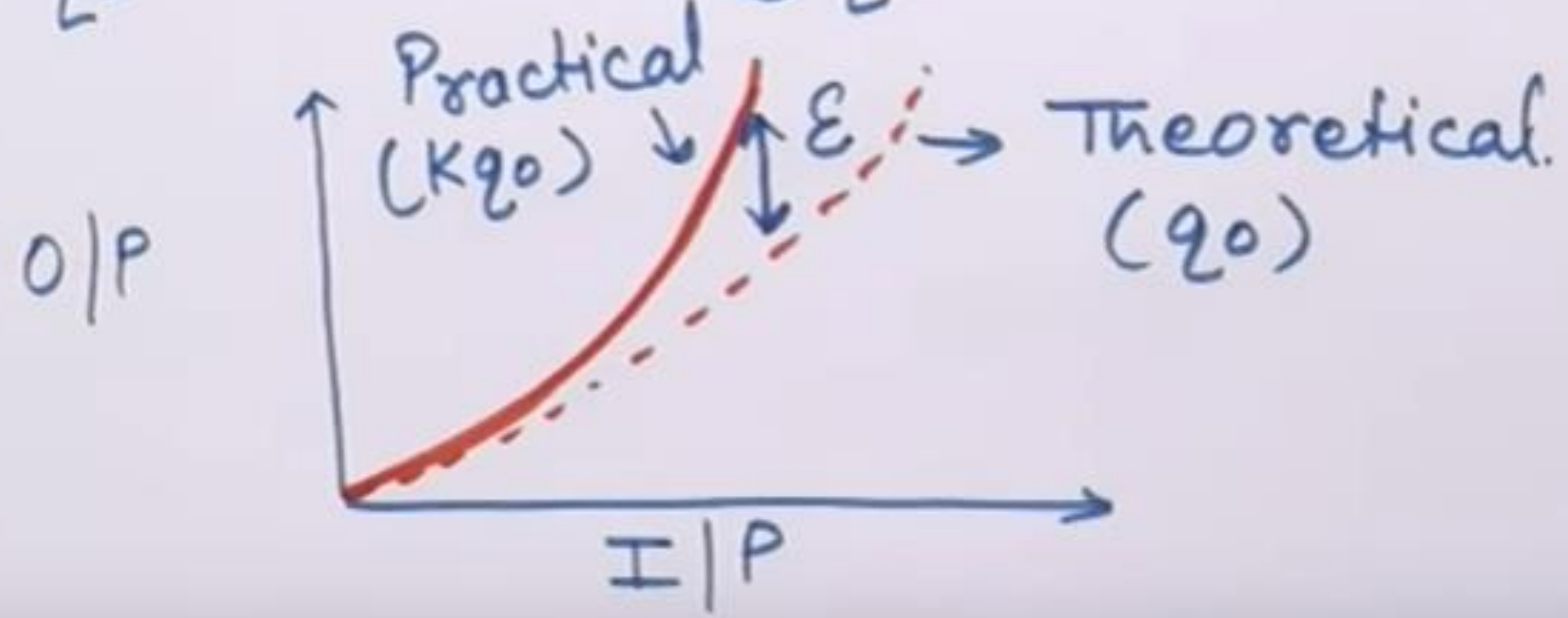
Zero error → output deviates from the input by a constant factor over the entire range of the transducer.



Sensitivity Error →

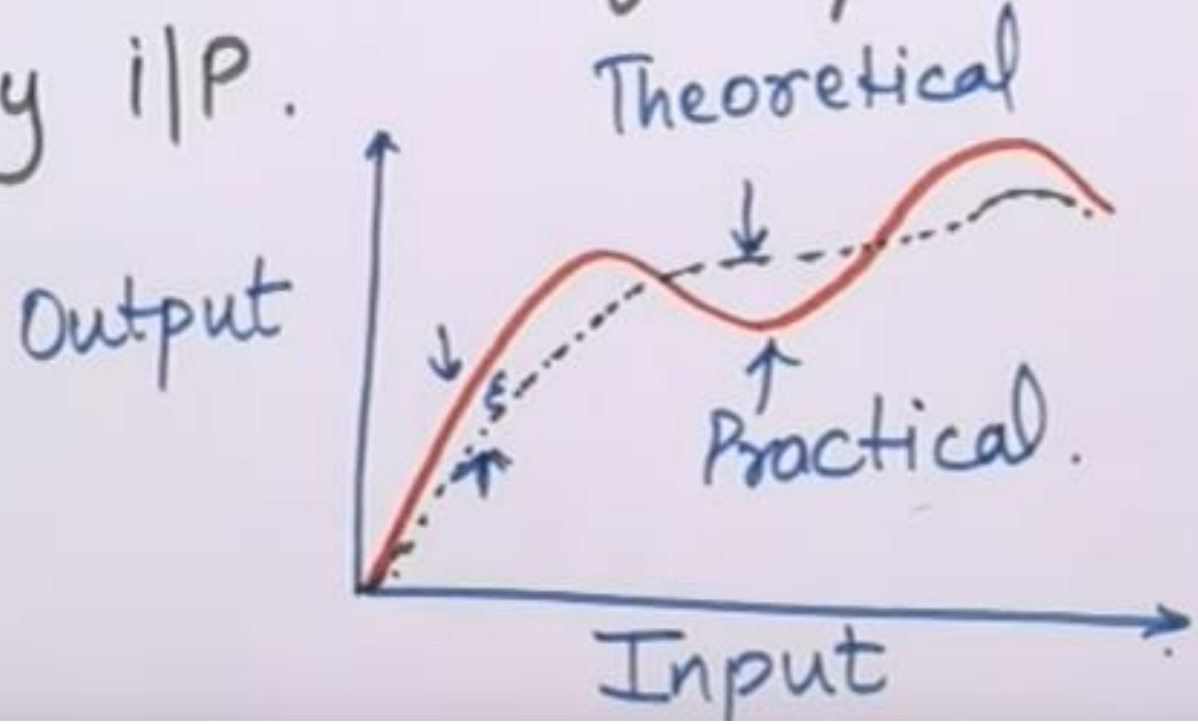
* The observed O/P deviates from the correct value by a constant value.

* $q_0 \longrightarrow K q_0$



3) Non-conformity →

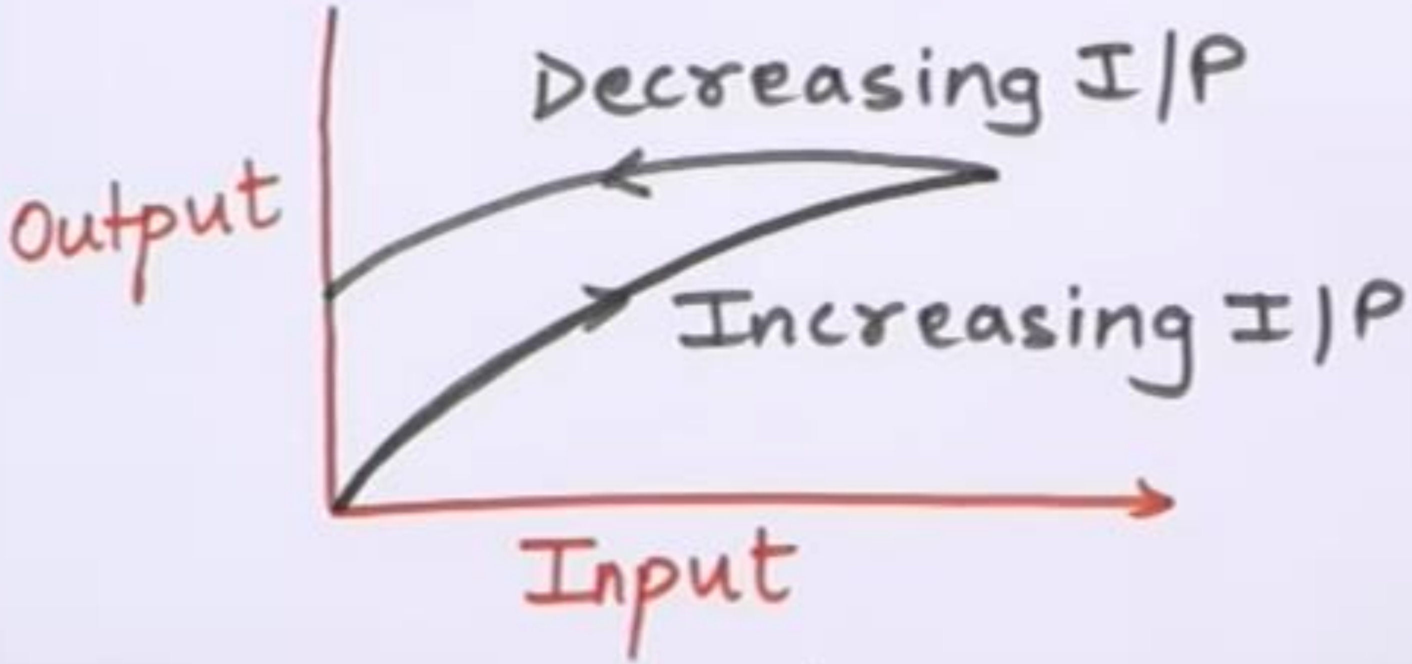
It occurs when experimentally obtained transfer function deviates from the theoretical transfer funⁿ for almost every i/P.



4) Hysteresis →

* The output of a transducer not only depends upon the input quantity but also upon input quantities previously applied to it.

* A different output is obtained when the same value of input quantity is applied depending upon whether it is decreasing or increasing.



* Dynamic error :→ It occurs when the i/p quantity is varying with time.

Example → R-C series circuit.

step input ⇒ E $\qquad E$

time t.

$$e_c = E\left[1 - \exp(-t/\tau)\right]$$

τ = time constant = RC.

Dynamic or measurement error ⇒

$$e_m(t) = E - e_c$$

$$= E - E\left[1 - \exp(-t/\tau)\right]$$

$$\boxed{e_m(t) = \exp(-t/\tau)}$$

* **Error due to noise and drift** →

  ↓ signal of randam amplitude and random frequency

  ↳ slow change with time.

* **Error due to Frequency Change** :→

sine wave. → [Linear Transducer] → sine wave

Output Characteristics

1) Type of electrical output :→

→ O/P from the transducer may be a voltage, current, impedance or a time function of these amplitudes.

→ These quantities may not be acceptable to latter stages of instrumentation system.

→ Their magnitudes have to be cha
manipulated or changed in the
format by signal conditioning.

2) Output impedance →

* Z_o determines the extent to which the subsequent stages of instrumentation is loaded.
* Z_o ⇒ zero if no loading effects are there.
* If the o/p impedance is low compared to forward impedance of the system constant voltage source.

*) Useful Operating Range →

* O/P range of transducer is limited by the noise which can contaminate the i/P signal.
* The upper limit is set by the maximum useful input level. ~~the~~

Linear Variable Differential Transformer (LVDT)

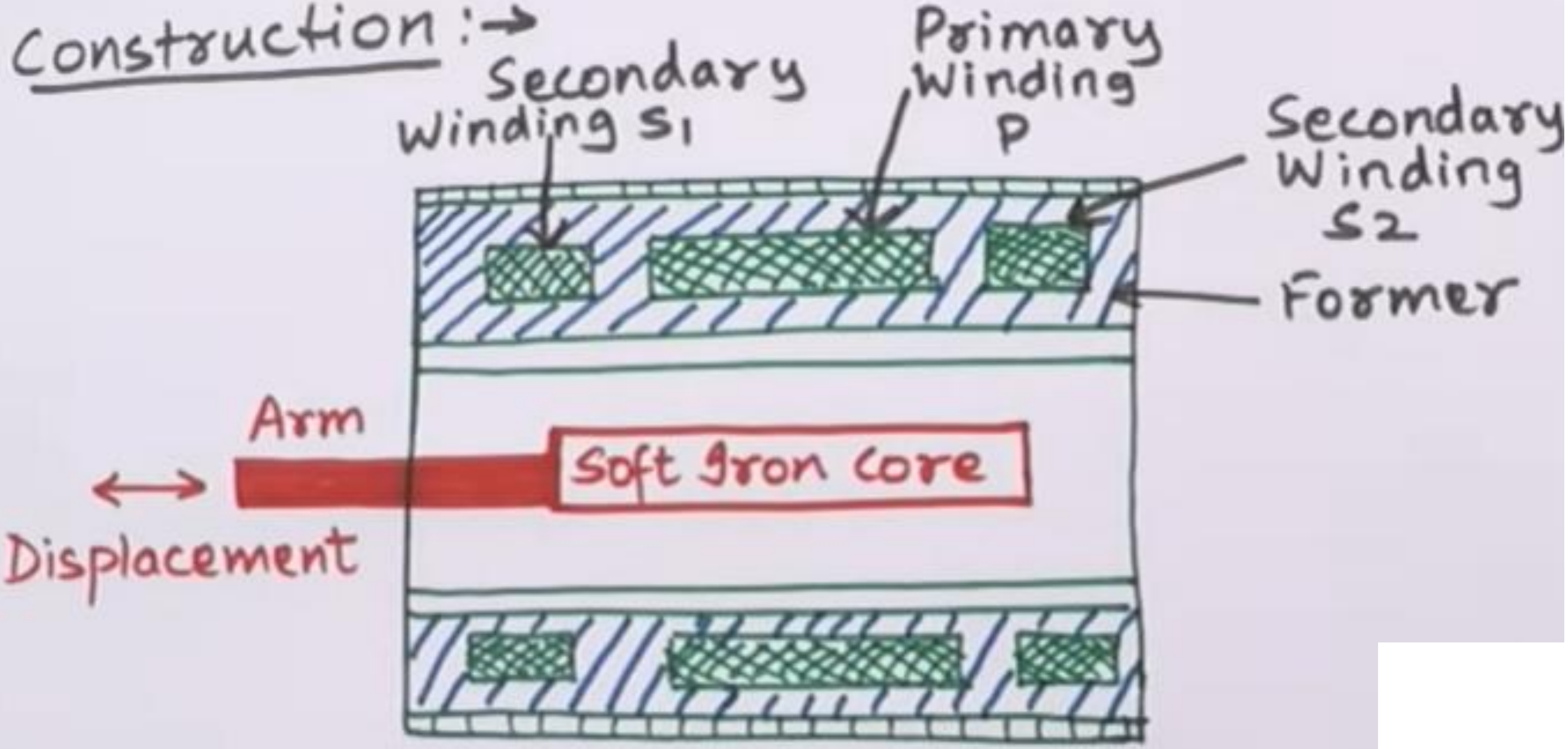
* It is a type of inductive transducer which is used to measure the displacement.
  ↓
  voltage.

* convert / translate the linear motion into electrical signals.

* Transformer < Primary winding, secondary wind

* Differential — O/P voltage is the difference of the voltg

Construction :→



* single primary winding P
* two secondary windings S_1 and S_2
* wound on a cylindrical former.
* equal number of turns and are identicall
placed on either side of primary.

connected to an alternating current
source
* soft iron core is placed inside the
* displacement to be measured is applied
to the arm. attached to soft iron
core.

* soft iron core is made of high permeabil[illegible] nickel iron which is hydrogen annealed.
* low harmonics, low null voltage and high sensitivity.
* slotted longitudinally to reduce eddy currents losses.
* assembly is placed in stainless steel housing and the end lids provide electrostatic and electromagnetic shielding.

Working :→

* Primary winding excited by a.c. source

↓

Produces an electromagnetic field.

↓

induces alternating currents voltages in two secondary windings.

$S_1 \longrightarrow E_{S1}$ series opposition.

$S_2 \longrightarrow E_{S2}$

The output voltage is difference of the voltages in the two windings.

$$\boxed{E_0 = E_{S1} - E_{S2}}$$

Core is at Null position →

$$E_{S1} = E_{S2}$$

$$\boxed{E_0 = 0}$$

Core is moved to the left of Null position →

$$E_{S1} > E_{S2}$$

In phase with the primary voltage. $\boxed{E_0 = E_{S1} - E_{S2}}$

core is moved to the right of null position →

$E_{s2} > E_{s1}$

$$\boxed{E_0 = E_{s2} - E_{s1}}$$

o/p voltage is 180° out of phase with primary voltage.

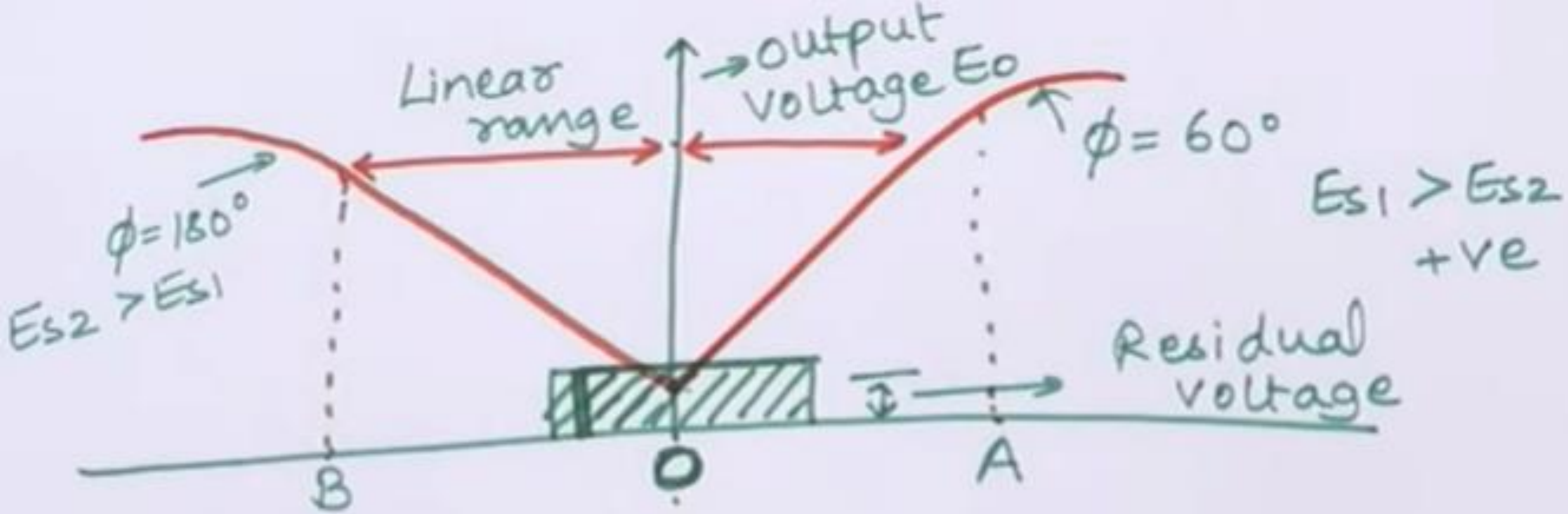
* The amount of voltage change in either secondary winding is proportional to the amount of movement of core

$E_{s1} > E_{s2}$ $\qquad$ $E_{s2} > E_{s1}$

$E_{s1} - E_{s2}$ $\quad$ +ve

-ve $\quad$ 180°

* The amount of output voltage may be measured to determine the displacement
* The O/P signal may also be applied to a recorder or to a controller that can restore the moving system to its normal position.
* O/P voltage of LVDT is a linear function of the core displacement within a limited range of motion say 5 mm from the null position.



$$\left.\begin{array}{l} O-A \\ O-B \end{array}\right\} 5\text{ mm.}$$

Residual voltage → small voltage at null position

↓

* due to presence of harmonics in the supply voltage
* due to harmonics produced in output voltage on account of use of iron core
* either an incomplete magnetic or electric unbalance.
* 1% of maxm o/p.
*

Advantages of LVDT

1) High range →

range of displacement that can be measure

1.25mm to 250mm.

0.25% full scale linearity → 0.003mm

Dynamic response is slow.

2) Friction and Electrical Isolation:-

no physical contact between core and coil.

* no wear and tear due to friction.
* no damage of instrument parts

* gives infinite resolution throughout its operating life.

3) Immunity from external effects :⇒

* separation between core and coil permits the isolation of pressurized, corrosive or caustic fluids.

4) High input and high sensitivity →

+ LVDT give a high o/P.

*. High sensitivity of about 40V/mm.

5) Ruggedness → can tolerate highshock and vibrations.

6) Low Hysteresis → LVDT shows low hysteresis → repeatability is excellent.

7) Low Power Consumption :→

Disadvantages of LVDT :→

* relatively large displacements are difficult to measure.
* sensitive to stray magnetic and electric fields.
* performance affected by vibrations.
* temperature also affects its performance.
* Dynamic response is slow.

Uses / Applications of LVDT :→

1) Primary Transducer
2) Secondary Transducer

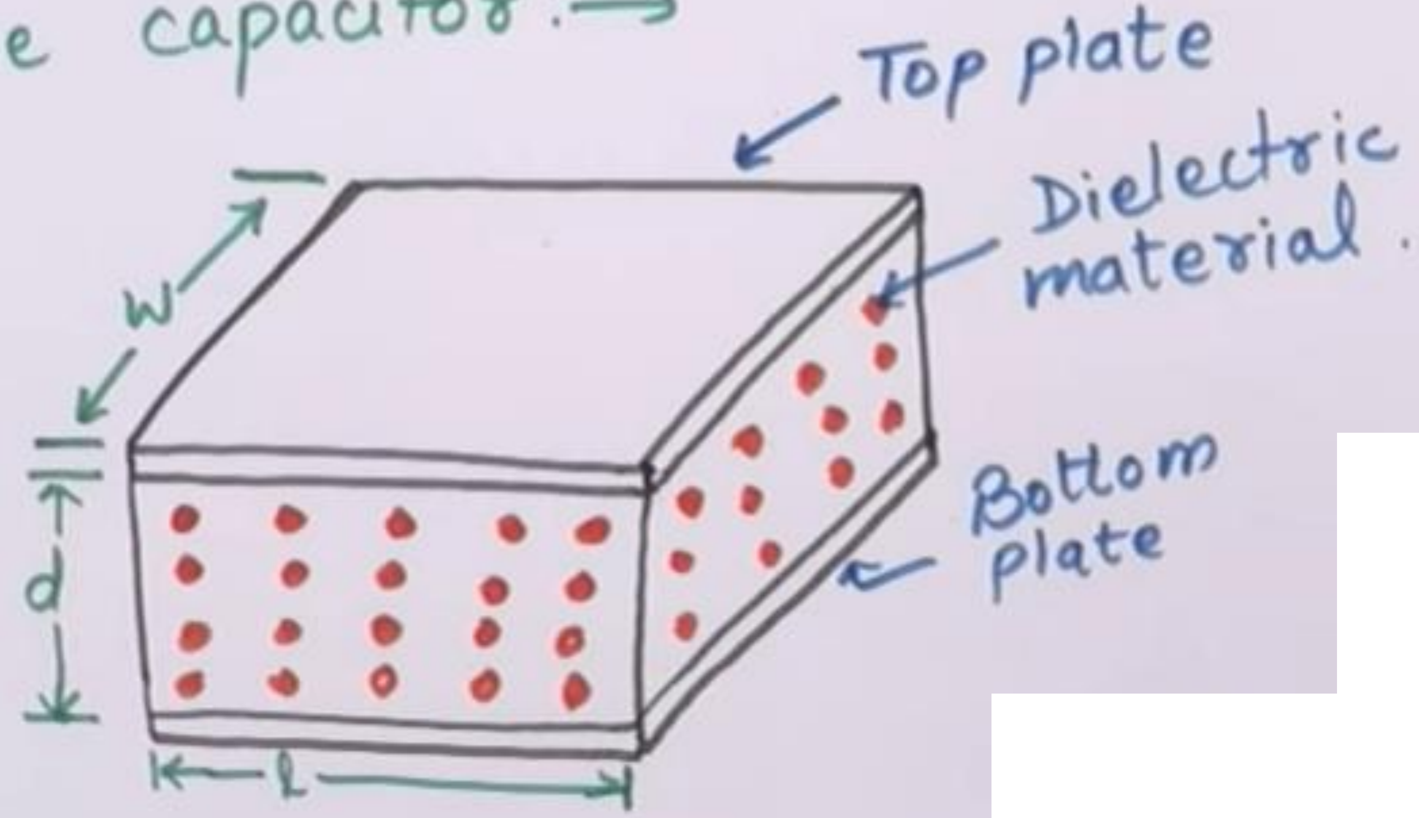
Capacitive Transducers

* Capacitive Transducers convert a non-electrical quantity into an electrical quantity by means of changes in capacitance.

→ displacement, force, pressure, flow, level, torque etc...

voltage, current.

* The principle of operation of capacitive transducers is based on the equation of capacitance of a parallel plate capacitor:→



$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

ε = permittivity of medium $= \varepsilon_r \varepsilon_0$

ε_r = relative permittivity

ε_0 = permittivity of free space $= 8.85 \times 10^{-12}$ F/m

A = overlapping area of plates

d = distance between two plates.

* The capacitive transducer work on the principle of change of capacitance which may be caused by →

(i) change in overlapping area, A
(ii) change in distance d between the plates
(iii) change in dielectric constant.

↳ displacement, force, pressure, liquid level/flow. .

* The capacitance is measured with bridge circuits.
* output impedance $X_C = \frac{1}{2\pi f C}$ → capacitance

  f → frequency

Advantages of Capacitive Transducers :→

1) They require extremely small forces to operate them and hence are very useful for use in small systems.
2) They are extremely sensitive.
3) Good frequency response.
4) High input impedance so less loading effects.
5) A resolution of the order of 2.5×10^{-3} mm can be obtained.

6) The force requirements is small so require small power to operate them.

Disadvantages of Capacitive Transducers

1) The metallic parts of the transducers must be insulated from each other in order to reduce the effects of stray capacitances.

2) Show non linear behaviour on account of edge effects.
Guard rings are used to eliminate this effect.

iii) output impedance is high on account of their small capacitance value which leads to loading effects.

iv) The cable connecting the transducer to the measuring point is also a source of error.

Application / Uses of Capacitive Transducers :→

i) They can be used for measurement of both linear and angular displacements.

* Capacitive transducers can measure extremely small displacements down to the order of molecular displacements i.e. 0.1×10^{-6} mm.
* They can be used for meas. of large displacements upto 30 m as in aeroplane altimeters.
*

ii) capacitive transducers can be used to measure the force and pressure.

$\downarrow$

displacement

$\downarrow$

change in capacitance

iii) They can also be used as direct pressure tranducers in all those cases where the dielectric constant of a medium changes.

v) They are used in conjunction with mechanical modifiers for measurement of volume, density, liquid level, weight etc.

dielectric constant

↓

capacitance.