MVPS's Rajarshi Shahu Maharaj Polytechnic, Nashik

Mechanical Engineering Department

Mechanical Engineering Measurement (22443)

Class: ME4I

Unit 01: Introduction to Measurement

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Course Outcome:
Students should able to use relevant instrument for measuring displacement.

Unit Outcome:
Students should able to

1a. Identify different characteristics of give instrument.
1b. Identify errors in given instrument.
1c. Classify the transducer for given application.
1d. Identify given contact and non-contact transducer with justification.

1)What is measurement? Explain its significance.

Measurement is the process of comparing the various characteristic of an object with the various characteristic of standard object.

Significance of Measurement

 It is important in various areas of atomization for: indicating function, controlling function, recording function and also in Research and Development activity.

 The inaccurate measurement leads to the incorrect results and hence the incorrect process control.

 Example: Ships and aeroplanes can navigate confidently without the help of the sight of land, only because of precise angular measurement.

 In indicating function controlling function, recording function also in research and development activity. Linearity

 Output signal is proportional to the change in input signal

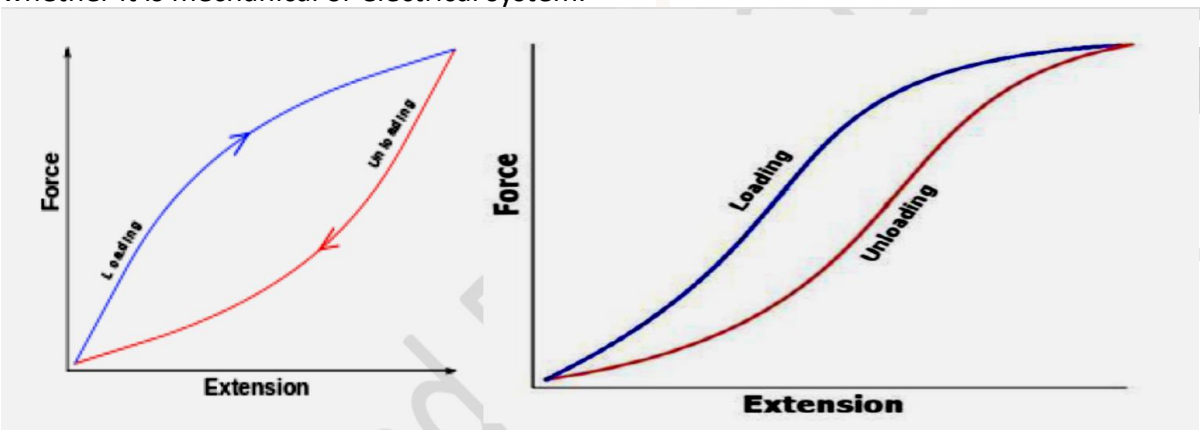
 In commercial instruments, the maximum departure from the linearity is often specified in the following ways:

 Independent of the input: if the deviations of the output of the instrument from best fitting straight line does not vary with the input, then non-linearity is specified in the terms of higher value of the maximum deviation that occurs on the positive and negative sides of the best fitting or idealized straight line.

 Propositional to input: If the deviation of the output of the instrument from the idealized straight line varies with the input, then non-linearity is specified as the function of the input. In such a cases, the maximum deviation of points on the positive and negative sides of the idealized straight line is joined it the origin and their slopes determined. Most of the instrument requires linear behaviour as it gives linear scale which is desirable.
 This is because the conversion from a scale reading to the corresponding measured value of input quantity is most convenient if one merely has to multiply by a fixed constant rather than consult a non-linear calibration curve.

2)Define: hysteresis, speed of response, fidelity, Dynamic error, overshoot.

Hysteresis: It is a phenomenon, which gives different output effects when loading and unloading, whether it is mechanical or electrical system.



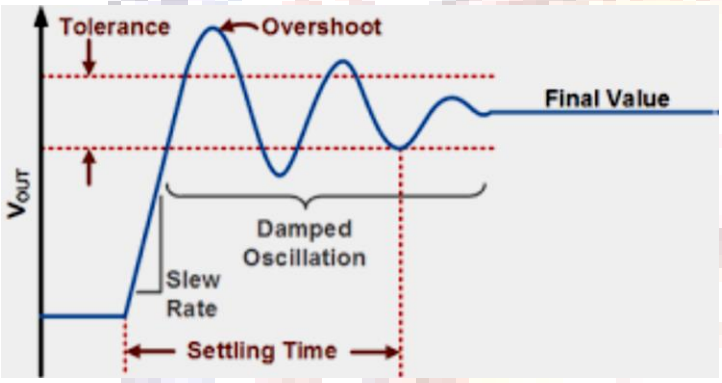
It arises due to the fact that all the energy input into the stressed part when loading is not reversible on unloading due to second law of thermodynamics, which rules out any perfectly reversible process.

Speed of response: It is defined as, the rapidity with which a measurement system responds to change in measured quantity.

Fidelity: fidelity is the degree of closeness with which the measuring instrument indicates or records a changing value of variable input. It is the ability of system to reproduce the output in the **same form as input.**

DYNAMIC ERROR: The difference between the indicated quantity and the true value of the time varying quantity is the dynamic error; here static error of the instrument is assumed to be zero.

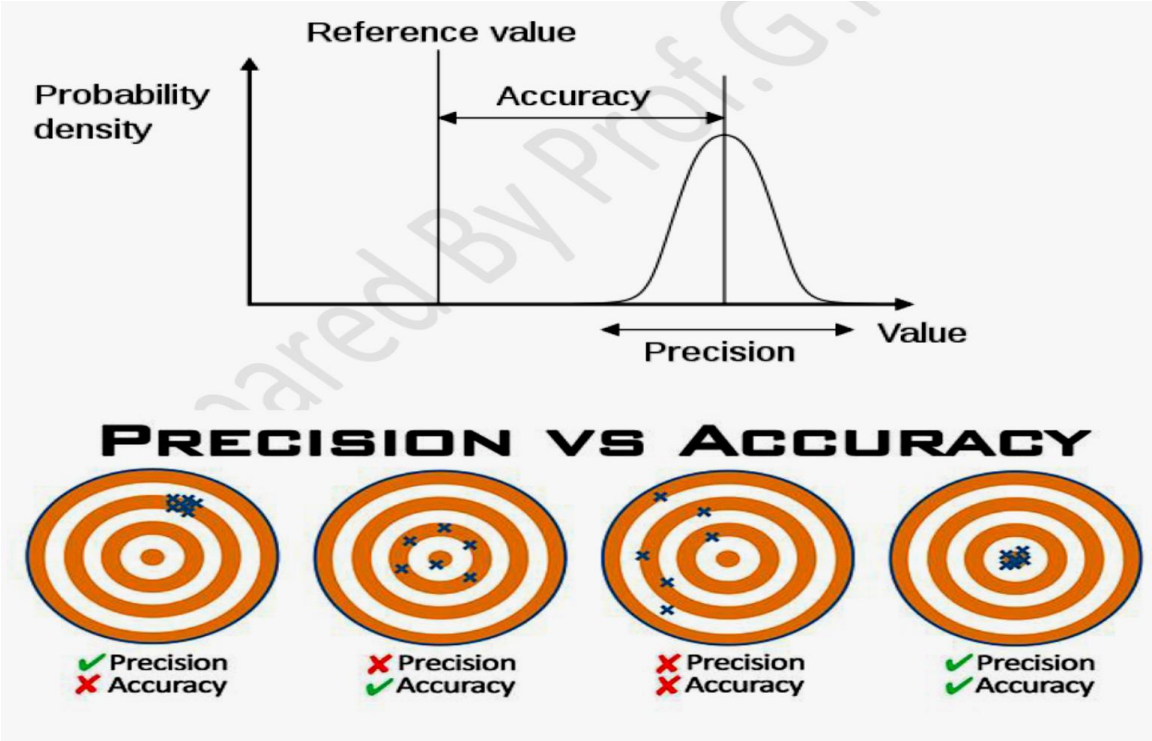
Overshoot: It is the maximum amount by which the pointer moves beyond the steady state. Pointer of an instrument does not come to rest in final deflected position.
It happens due to mass and inertia of moving parts.



3)State and define four desirable and four undesirable characteristics of measuring instruments.

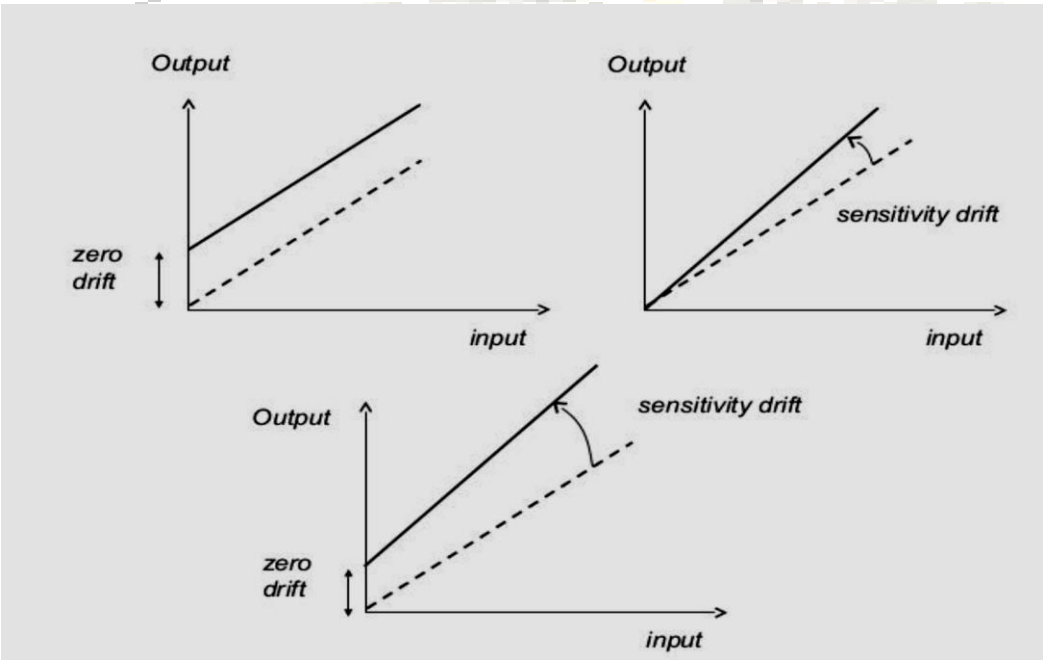
Desirable characteristics: accuracy, precision, sensitivity, reproducibility, repeatability, resolution etc.
Accuracy: It is the closeness or agreement of measurement value with true value.

Precision: The difference between two consecutive reading measured by instrumentation system is known as Precision. High precision means tight cluster of repeated results and low precision means broad scattering of results.



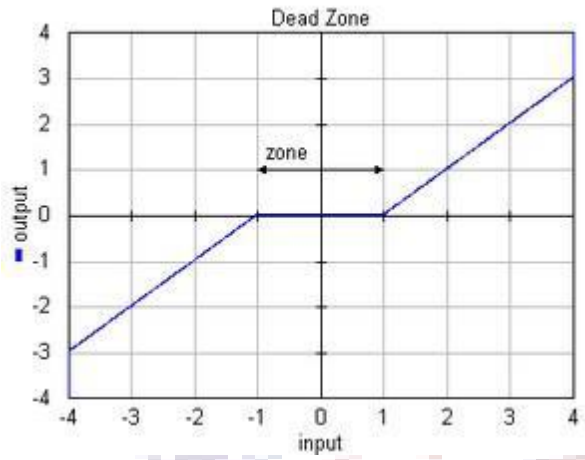
Sensitivity: It is the ratio of the magnitude of the output signal to the magnitude of the input signal or quantity being measured.
Reproducibility: The closeness or agreement between independent results is obtained with the same method on identical test material but under different conditions.
Resolution: It is the smallest measurable input to cause measurable change in output.

Undesirable characteristics: drift, measuring lag, dead zone, dead time, hysteresis, overshoot, backlash etc.
Drift: drift is the undesirable change or a gradual variation in output over a period of time that is unrelated to change in input, operating conditioning, or load



Measuring lag: it is the retardation or delay in the response of a measuring system to change in measured quantity.

Dead zone: it is range of values of a measured variable to which instrument does not respond. E.g. the input applied to the measurement may not be enough to overcome friction.



Dead Time: it is the time required by the measurement system to begin to respond to a change in the measurand.

Backlash: the maximum distance or angle through which any part of a mechanical system may be moved in one direction without applying appreciable force or motion to the next part in a mechanical system is called backlash.

4)Define the term Threshold, Resolution, Repeatability and Reproducibility, Range, Span.

Threshold:

It is defined as the minimum value of input below which no output can be detected. It is instructive to note that the resolution refers to the smallest measurable input above the zero value.

Resolution:

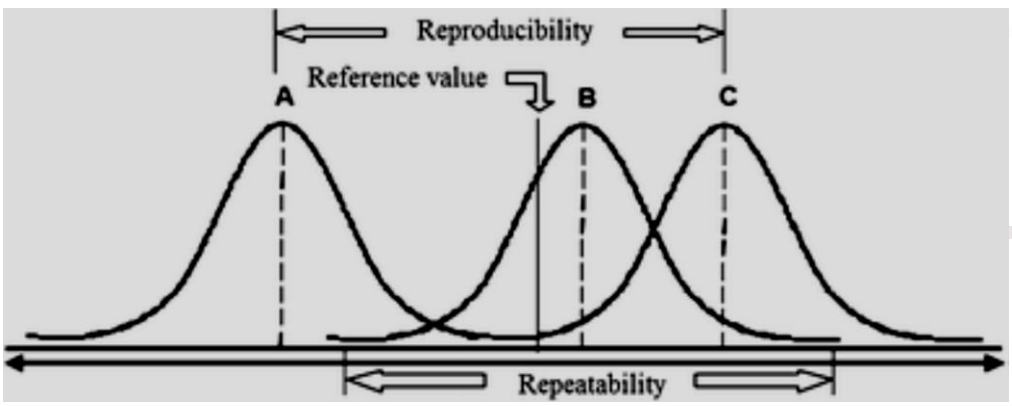
It is defined as the smallest increment in the measured value that can be detected with certainty by the instrument. In other words, it is the degree of fineness with which a measurement can be done.
Least count of any instrument is taken as resolution of the instrument.

Repeatability:

It can be defined as the ability of the instrument to reproduce a group of measurements of the same measured quantity, made by the same observer, using the same instrument, under the same conditions.

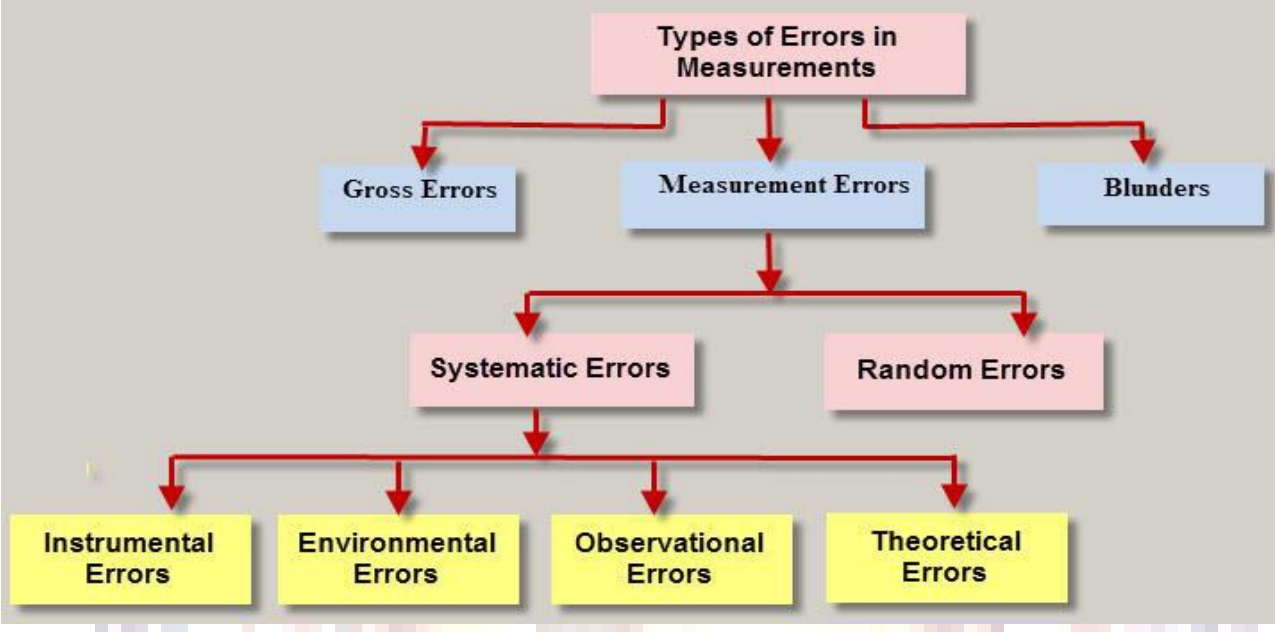
Reproducibility:

Reproducibility is the consistency of pattern of variation in measurement i.e. closeness of the agreement between the results of measurements of the same quantity, when individual measurements are carried out: ..by Different observer, Different instruments under differential conditions, locations, time etc..
It may also be expressed quantitatively in terms of the dispersion of the results.



Range
It can be defined as the measure of the instrument between the lowest and highest readings it can measure.
A thermometer has a scale from −40°C to 100°C. Thus the range varies from −40°C to 100°C.

5)Explain: observation and instrument error.



A) Personal error
Human mistakes in reading instrument. recording and calculating. inaccurate conversion of units. inaccurate estimate of average reading. due to
i) Individual limitation/skill
ii) Lack of experience
iii) Observational error such as parallax error

2) Operational error
Error associated due to improper alignment or assembly.
Improper method of operation.
e.g. thermometer will not show proper reading if its thermal bulb not installed properly. in ultrasonic test, error due to improper use of probe with body.
• Flow meter give wrong readings if it is installed near bend of pipe or immediate after valves.
Instrument error:
Classified as
i) Assembly errors ii) Random errors

Assembly errors-
the assembly errors are the errors in the measuring instrument due to improper manufacturing of the instruments.
Some of the possible assembly errors:
A) Displaced scale
this is the incorrect fitting of the measuring scale. For instance the zero of pointer may not coincide with actual zero on the scale. Sometimes the scale gets cracked, thus showing the faulty readings.
B) Non-uniform scale
sometimes the scale of the measuring instrument is not divided uniformly. In some part of the scale the markings may be too close and in other parts too far.

C) The pointer is bent
This happens in many cases. The pointer may get bent in either horizontal direction or the vertical direction, in either case, is shows erroneous reading.
D) Manufacturing errors in the components
The instruments are made up of a number of small components, which may be manufactured in different places. Sometimes there are manufacturing errors in some of these components like gear, lever, links, hinges etc.

Random errors-
apart from the assembly errors there can be many other errors which may be very difficult to trace and predict, these are called as random errors.
A) Frictional errors
There are number of moving mechanical parts in the analogue measuring instruments. the friction between these components leads to errors.
due to friction some of the parts wear and tear, which further adds to the error of the instrument. hence, one should not use the analogue measuring instruments for long periods of time and replace with the good quality ones from time-to-time. mechanical vibrations:
when the instrument is used in vibrating place the parts of the instrument start vibrating giving faulty readings.
B) Backlash in the movement
This is the error due to time lag between the application of the parameter and the instrument showing reading. even though some value of the parameter changes, there is no indication.

C) Hysteresis of the elastic members
Over the period of time the elastic members tend to lose some elasticity leading to errors in the indicated value of the instrument.
D) Finite scale divisions
The scale marking can be made only up to certain limits and they not be hundred present accurate.

6) What is difference between accuracy and precision?

Sr. No.	Parameters	Accuracy	Precision
1	**Definition**	It refers to the closeness of a measured value to standard or known value.	It refers to closeness of two or more measurements to each other.
2	**Functionality**	It expressed as the limit of error of a measuring device.	It is composed of two characteristics, conformity & no of significant digits.
3	**Measure**	It measures conformity of truth.	It refers to degree of agreement within group of measurement.
4	**Dependent**	Dependent on systematic Error.	Dependent on Random Error.
5	**Determination**	By proper calibration.	By statistical analysis.
6	**Necessity**	Accuracy necessarily is with precision.	Precision in measurement does not guaranties accuracy.
7	**Formula**	Accuracy=Mean value -true value	Precision=Individual value-arithmetical

			mean value
8	**Measurement Means**	Conformity of truth	Clarity or sharply defined

7) What is calibration of instruments? Why it is done?

Calibration is the operation of making an adjustment or making a scale so that readings of an instrument conform to an accepted and a certified standard. It creates confidence of using instruments in users' mind.

 It is a process of establishing reliability of a measuring instrument. It involves visual inspection for obvious physical defects, proper installation according to manufacturer's specifications, zero settings, levelling etc.

 This involves the comparison of the instrument to be calibrated with primary standard, secondary standard or a known input source.

It is done for the following purpose,

I. It gives the opportunity to check the instrument against a known standard there by helping in evaluation of errors and accuracy.

II. To establish reliability of instrument.

III. To offer specified accuracy to instrument.

IV. To improve performance of instrument.

V. To minimize errors of measuring instrument.

VI. To conform linearity, hysteresis and repeatability of instrument.

8) Difference between Random and Systematic Errors.

Sr.No.	Parameters	Random Errors	Systematic Errors
1	**Risk**	Accidental	Non Accidental
2	**Size**	Small	Big
3	**Dependent Factor**	Independent	Dependent
4	**Cause**	Caused due to inconstant factors such as spring hysteresis, stickiness, and friction, noise and threshold limitations.	Caused due to sensitivity effects, zero offset and known non linearity.
5	**Magnitude and Direction**	Magnitude and direction cannot be predicted from knowledge of measurement	Way to locate these errors is to have repeated measurements under different conditions

		system.	or with different equipment and if possible by different method.
6	**Law**	Errors are assumed to follow the law of probabilities.	Cannot be determined by the direct and repetitive observations of the measurand made each time with the same technique.
7	**Noise**	More	Less
8	**Linearity**	Moderate	Non-Linear

9) Define transducer. Explain the classification of transducer with suitable example.

A transducer senses the desired input in one physical form and converts it to an output in another physical form.
The transducers may be classified as
a) Passive transducer: These transducers derive the power required for generating output from an external source of power. They may absorb a little energy from the process variable being measured. These are also called as externally powered transducers. e.g.: Resistive Thermometer, Inductive Differential Transducers, LVDT etc.
b) Active transducer: These transducers **do not** require external source of power to produce their output. e.g. Bourdon Tube, Mercury in Glass Thermometer.

The transducers are also classified based on working principles:
a) Resistive Transducer: This type of transducer converts the input into change in resistance. Ex: Resistance of metallic wire changes by elongation or compression. Strain Gauges positioning of slider varies the resistance in a potentiometer.
b) Inductive Transducer: These types of transducers convert the input into change in inductance. Ex: The differential voltage of two secondary windings varies linearly with the displacement of magnetic core, the L.V.D.T.
c) Capacitive Transducer: These types of transducers convert the input into change in capacitance. Ex: Variation in capacitance due to change in distance between two parallel plates. This principle is applied in variable capacitance Gauge.
d) Piezo Electric Transducer: An Emf is generated when external force is applied on certain crystalline materials such as Quartz.
e) Thermo Resistive: Resistance of pure metal wire with positive temperature coefficient varies with the temperature. Ex Resistance Thermometer.

10) What are active and passive transducers? Give two examples of each.

i) Active transducer: They generate equivalent electrical output signal without any external energy or energizing source.
Examples: thermoelectric transducer, piezo-electric transducer, photo-voltaic transducer etc.

ii) Passive transducer: the measurand is converted into passive parameter such as resistance, inductance or capacitance, **which needs an external electrical supply** so as to get an equivalent electrical output.

Examples: resistive transducer, inductive transducer, capacitive transducer, piezo- resistive transducer, thermo- resistive transducer

11) Difference between Active and Passive Transducer.

Sr. No.	Parameters	Active Transducer	Passive Transducer
1	**External Source**	Self-Generation Type	Requires External Source
2	**Energy Absorb**	From Physical variables	Absorb from external sources
3	**Principle**	Works on converging principle	Works on controlling principle
4	**Size**	Small	Large
5	**Design**	Simple	Robust
6	**Reliability**	More	Less
7	**Cost**	Less	More
8	**Examples**	e.g.: piezoelectric & photovoltaic	e.g.: Potentiometer, strain gauge, resistance thermometer

12) Capacitive Transducers

Working Principle: "Distance between two parallel plates is varied by an externally applied force.**"**
 As shown in the figure below, a capacitive transducer has a static plate and a deflected flexible diaphragm with a dielectric in between.

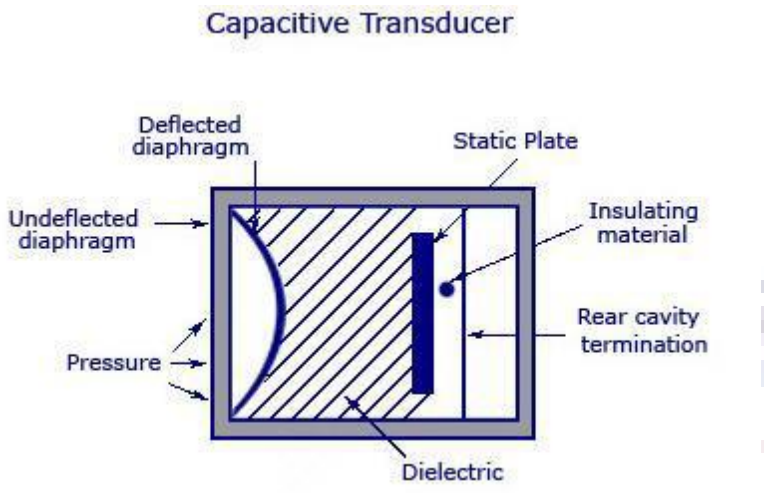
 When a force is exerted to the outer side of the diaphragm the distance between the diaphragm and the static plate changes.

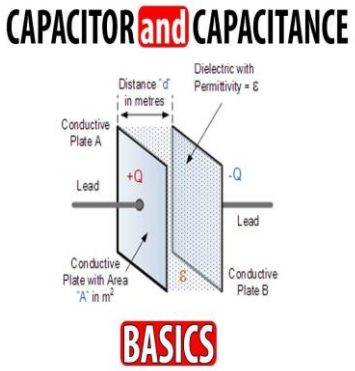
 This produces a capacitance which is measured using an alternating current bridge or a tank circuit.
 A tank circuit is more preferred because it produces a change in frequency according to the change in capacitance.

 This value of frequency will be corresponding to the displacement or force given to the input.

 Capacitance (C)= €A/d

Where,
€= Permittivity (f/m)
A= Area (square meter)
d=Distance(m)
 Thus, Capacitance can be change by changing area of plates, distance between plates or changing dielectric material.





Advantages
1. Small force requires to operate.
2. Extremely sensitive.
3. Good frequency response.
4. Small power requires to operate.

Disadvantages
1. Non-liner behaviour.
2. High output impedance.
3. Distance increases capacitance decreases.
4. It should have proper area.

Applications
1. To measure the linear displacement.
2. To measure the angular displacement.
3. To measure the humidity in gases.
4. To measure the volume, density, liquid level, weight.

13) How pressure is measured by piezoelectric transducer? Explain.

Working Principle: "An emf is generated when an external force is applied to certain crystalline materials such as **quartz crystal."**
Materials: Rochelle salt, ammonium dihydrogen phosphate, quartz and ceramic A and B etc.
 The main principle of a piezoelectric transducer is that a force, when applied on the **quartz crystal**, produces electric charges on the crystal surface.

 The charge thus produced can be called as piezoelectricity.

 Piezo electricity can be defined as the electrical polarization produced by mechanical strain on certain class of crystals.

 The rate of charge produced will be proportional to the rate of change of force applied as input.

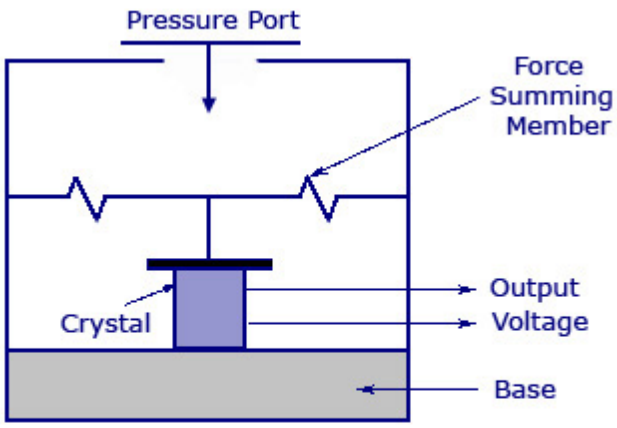
 As the charge produced is very small, a charge amplifier is needed so as to produce an output voltage big enough to be measured.

 The device is also known to be mechanically stiff. For example, if a force of 15 kilo N is given to the transducer, it may only deflect to a maximum of 0.002mm. But the output response may be as high as 100KiloHz.

 This proves that the device is best applicable or dynamic measurement. The figure shows a conventional piezoelectric transducer with a piezoelectric crystal inserted between a solid base and the force summing member.

 If a force is applied on the pressure port, the same force will fall on the force summing member.

 Thus a potential difference will be generated on the crystal due to its property.
The voltage produced will be proportional to the magnitude of the applied force



Piezo-Electric Transducer

Advantages
1. High material stability.
2. Ability to form into desirable shape.
3. Excellent high frequency response.
4. Negligible phase shift.

Disadvantages
1. High impedance charge requires an emitter follower.
2. These materials are water soluble.
3. Materials dissolve in a high humidity environment.
4. It has high temperature sensitivity

Applications
1. To measure the dynamic pressure.
2. To measure the sound intensity