Definition of measurement:

Measurement is a process of comparing input with pre-defined standard and giving the output.

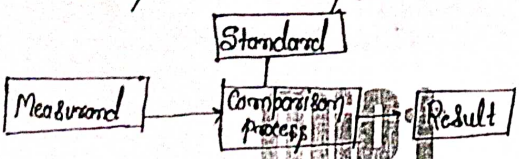
e.g :- How long is it = 2 meter

measurement of length is 2 meter

↳ It have two parts. one is number second is unit.

objective of measurement

The basic objective of measurement is to provide the required accuracy at a minimum cost.



Measurand: A physical quantity such as length, weight and angle to be measured.

Comparison: To compare the measurand with a known standard for evaluation.

Standard / Reference: The physical quantity or property to which quantitative comparisons are to be made, which is internationally accepted.

Modes of measurement:

Based upon the numbers of conversions, three basic modes of measurement have been developed.

1. Primary measurement
2. Secondary measurement
3. Tertiary measurement

1. Primary measurement:

– In this type of measurement direct observation and comparison is done.

→ Not involvement of any conversion.

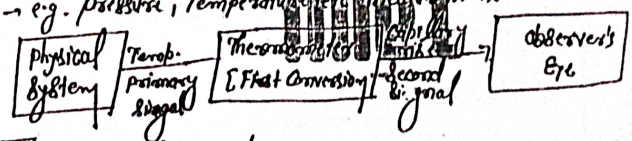
→ e.g. Length, Height, Depth etc measurement

2. Secondary measurement:

→ In this type of measurement, no-direct observation and comparison is done.

– Involvement of one conversion.

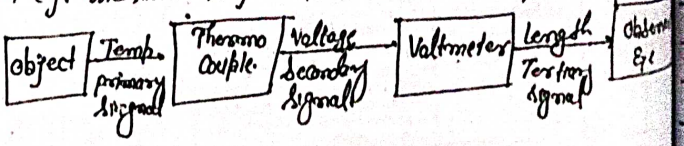
→ e.g. pressure, Temperature level measurement.



Tertiary measurement

– In this type of measurement, involvement of two conversion.

→ e.g. measurement of temp. with thermo-couple.



Methods of measurements:

In measurement system, there are various of methods are given below,

- Direct Comparison → Indirect Comparison
- Comparative method → Coincidence method
- Fundamental method → Contact method
- Transposition method → Complementary method.
- Deflection method.

→ **Direct Comparison**: Measurement are directly obtained by some instrument / tools.
e.g. Vernier, Scales.

→ **Indirect Comparison**: Measurement are obtained by some other quantities.
e.g. measurement of force can be obtained by measurement of strain by strain gauge.

Step1. Produced Strain (ε)

Step2. Produced Stress (σ) = $E\varepsilon$ ∴ E = young's modulus

Step3. Produced force (F) = $\sigma \times$ Area.

→ **Comparative method**
- Results obtained by Compared with other known value.
- e.g. Comparator.

- **Coincidence method**:
  → Results obtained by coincide with certain lines and signals
  e.g. Comparator

Transposition method:
- In this method quantity to be measured is first balanced by a known value and then balanced by an other new known value.
→ e.g. Determination of mass by balancing method.

Complementary Method:
- The value of quantity to be measured is combined with known value of the same quantity.
- e.g. determination of the volume of a solid by liquid displacement volume.

Deflection method:
- The value to be measured is directly indicated by a deflection of pointer.
- e.g. Pressure measurement by bourdon gauge.

Q.1 What do you mean by measurement? What are the different methods of measurement?

Sol: Refer to page No: 2 & page No: 3

Q.2 With a block diagram, explain the three stages of a generalized measurement system giving suitable e.g.

Sol:
1. **Primary Sensing element**: Which senses the quantity under measurement
2. **Variable Conversion element**: That modifies suitably the output of primary sensing element.

3. Data presentation element :- That render the indication on a calibrated scale.

Next refer to page No: 03 to 04

Generalised Measuring System & functional Elements

Any measuring system generally composed of three basic element. These are:

1. Initial sensing elements
2. Signal conditioning elements
3. Reading-recording elements.

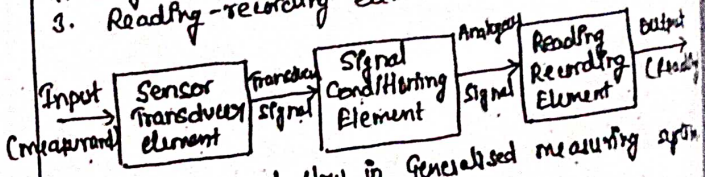
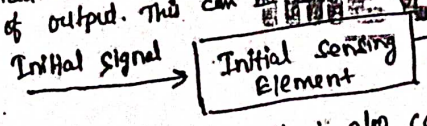


Fig: Signal flow in Generalised measuring system

① Initial Sensing element
It is first element which detects or senses the measurand
It is the part which first receives signal from measurand medium & converts this signal into more convenient form of output. This can be done by simple block diagram



Initial sensing element is also called transducer element
" A transducer is a device which convert desired input in one physical form into an output in another physical form.

Common example of transducer element are:

(i) Solar cell → convert light to voltage
(ii) Thermocouple → temp. change to voltage
(iii) Hg thermometer → temp change to displacement
(iv) Manometer → Pr. to displacement
(v) LVDT → Displacement to change in inductance

② Signal Conditioning Elements
These elements are used to modify the transduced information into a form that is acceptable to reading-recording elements. These include.
(a). Variable transformation element.
(b). Variable manipulation element.
(c). data transmission element.

(a). Variable transformation element: The output signal given by the initial sensing element is converted into another suitable form while preserving the information content of original signal. This is done by Variable transformation element. It can be represented by following block diagram.

(b) Variable Manipulation Element: Many times, the output of transducer is so small that is insufficient to indicate of measure. Hence these output are manipulated or amplified by manipulation element.

(c) Data Transmission element: When the functional elements of a measuring instruments are physically separate, it would be necessary to transmit information or data from one element to another using data transmission element. Ex. Shaft & Gears are used to transmit power from one location to other, radio transmission from Satellites.

③ Reading-Recording Elements: They are also known as data presentation element. This element is used to display information of measured quantity to observer.

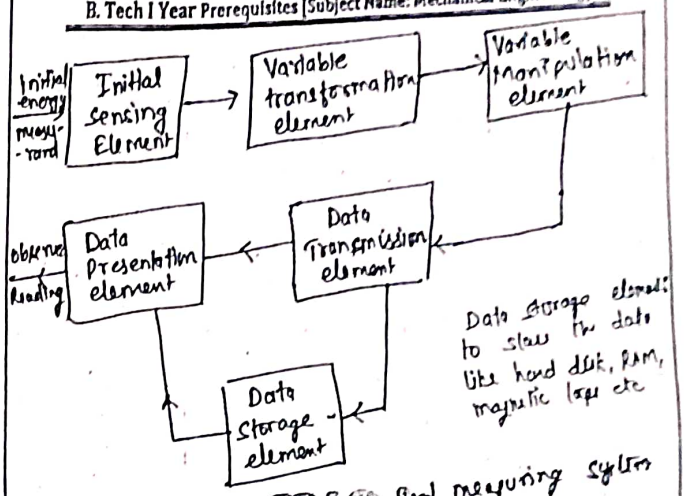


Fig: Block diagram of Generalized measuring system

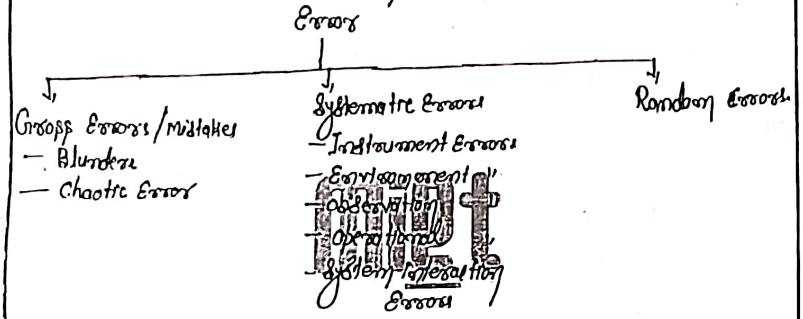
Errors in measurement.

- What is error?

→ It is defined as a difference between indicated or measured value and true value.

- It is impossible to make measurement with perfect accuracy.

Types of Error: Errors are mainly three types



Gross Errors:

- Human Mistakes
- Careless reading, Mistake in recordings
- Can not treated mathematically
- Can be avoided only by taking care in reading and recording.

Systematic Errors.

- Have definite magnitude and direction.
- Can be repeated consistently with repetition of experiments.
- To locate these errors: Repeated measurements under different

conditions or with different equipment or possible by any other different methods.

- Instrumental Errors:
  - Limiting accuracy
  - Due to design or construction
  - Improper selection of instrument
- Operational Errors
  - Misuse of instrument
  - Poor operational techniques
- Environmental Errors
  - Due to external conditions for the measuring instrument
  - Such as effects of change in temperature, humidity, barometric pressure.
- Observation Errors
  - Due to poor capabilities and carelessness of operator
    ex. parallax Error.

Systematic Errors	Random Errors
1) Repetitive in nature	1) Random in nature.
2) These errors result from improper conditions and procedures.	2) These errors are inherent in measuring system.
3) Controlled in magnitude and sense	3) Accident in nature and difficult to control.

ment or possible by any entirely

nt

the measuring instrument
temperature, humidity, barometric

Close closeness of operation

Random Error

- Random in nature.
- These errors are inherent in the measuring system.
- Accident in nature and difficult to control.

Systematic Error	Random Error
4) After proper analysis these errors can be reduced or eliminated. 5) eg. Parallax error, Calibration error etc	4) Can not be eliminated 5) Slight displacement of measuring joint, friction of moving parts, Combined effect etc.

Calibration in measurement

→ Instrument Calibration is one of the primary processes used to maintain instrument accuracy.

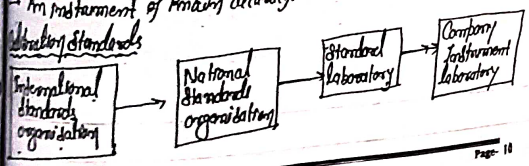
'OR'

- Calibration is an activity of checking the accuracy and precision of measuring instrument by Comparing it with standard.
- Calibration provides Confidence in testing and reduces errors while calculating the measurements.

The procedure of Calibration involves—a Comparison of the particular instrument with either:

- A primary Standard
- A secondary standard with a higher accuracy than the instrument to be Calibrated.
- An instrument of known accuracy.

Calibration standards



ISO → Make globally acceptable rules

NSO → Make Country level rules and parameter

Standard laboratory – check and certified

Company standards – Working standards.

Q.1 Explain the term error in measurement. what are different types of errors?

Sol^n: Refer to page No: 8 & page 9

Q.2 Explain the difference between systematic errors and random errors? what are the typical sources of these two errors?

Ans: Refer to page No 9 & 10

Q.3 what is Calibration and Standards?

Ans: Refer to page No 10

Q.4. what is the basic principle of Calibration?

Ans: - Calibration is the activity of checking, by Comparison with a standard, the accuracy of a measurement instrument or type. It may also include adjustment of the instrument to bring it into alignment with the standards. Even the most precise measurement instrument is of no use if you Cannot be sure that it is reading accurately or more realistically that you known that the error of measurement.

Q.5 What are the types of calibration?

Ans: Calibration is basically divided into three types.
- Transducer
- data system
- physical and visual calibration

Q.6 What do you mean by calibration of any instrument?

Ans: Refer to page No: 10

Q.7 Explain various errors in measurement and the practice which are needed to be minimize them.

Ans: Refer to page No: 89 page 3

Q.1 State the four different pressure measurement scale:

Ans: 1. Gauge: - Reference to Atmospheric pressure.

2. Sealed: Reference to sealed chamber filled with atmospheric pressure.

3. Absolute: Reference to vacuum or zero pressure.

4. Differential: where devices has two ports for the measurement of two different pressure.

Q.2 With the neat diagram, explain the relationship between absolute, gauge and barometric pressure.

Ans: Pressure on a fluid [illegible] two different types
1. Absolute pressure
2. Gauge pressure.

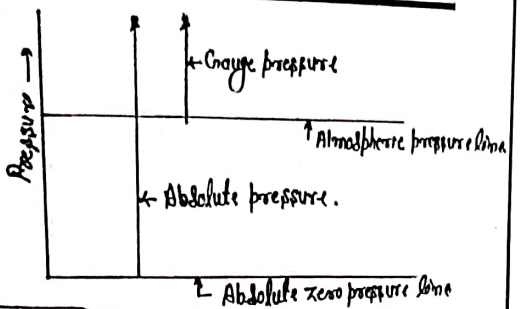
1.) Absolute pressure: It is defined as the pressure which is measured with reference to absolute zero pressure.

2) Gauge pressure: It is defined as the pressure which is measured with reference to atmosphere pressure. Whether it is above atmospheric pressure is zero or. The is measured with the help of the instruments.

Absolute Pressure = Atmospheric p
Gauge

Q) Explain the working of a Bo
neat sketch

Ans: Bourdon tube pressure Gauge
Principle: The bourdon tu
that a bent tube will cha
a circle internally, whe
tube straightens and returns
to its original form when
the pressure is released.
The tips of the tube
moves and the Pressure/
Pressure change and is
easily connected with a
pointer over a scale.



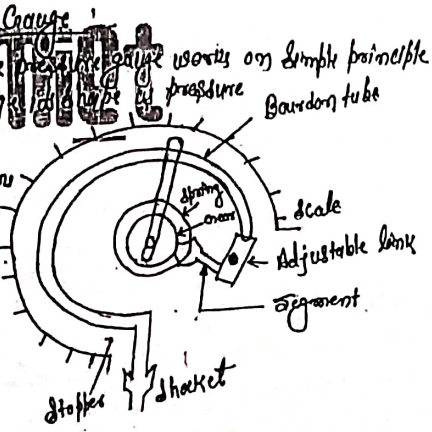
Absolute Pressure = Atmosphere pressure + Gauge pressure

Q.3 Discuss the working of a Bourdon tube pressure gauge with neat sketch.

Ans: Bourdon tube pressure Gauge:

Principle: The bourdon tube pressure gauge works on simple principle that a bent tube will change its shape if pressure is applied internally, the tube straightens and returns to its original form when the pressure is released.

The tips of the tube moves with the internal pressure change and is easily converted with a pointer onto a scale.

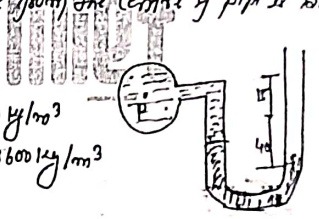


Q.4. Write a note on vacuum and high pressure measurement.

Ans: Vacuum pressure: To measure pressure below atmospheric pressure.

High Pressure: To measure pressure for above atmospheric pressure

Q.5. A simple U-tube manometer containing mercury is connected to pipe in which fluid of Sp. gravity 0.8 and having vacuum pressure is flowing. The another end of manometer is open to atm. Find the vacuum pressure in pipe if pressure level difference in manometer limb is 40cm and height of fluid in left tube from the centre of pipe is 15cm.



Sol: $S_1 = 0.8$

$S_2 = 13.6$

Density of fluid 1 $= \rho_1 = 800 \text{ kg/m}^3$

" " " 2 $= \rho_2 = 13600 \text{ kg/m}^3$

$h_2 = 40\text{cm} = 0.4\text{m}$

$h_1 = 15\text{cm} = 0.15\text{m}$

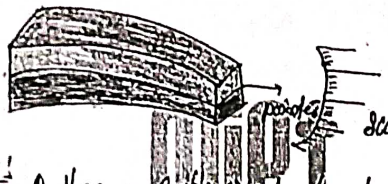
$P + \rho_2 g h_2 + \rho_1 g h_1 = 0$

$\therefore P = -5.454 \text{ N/cm}^2$

⊗ -ve shows vacuum.

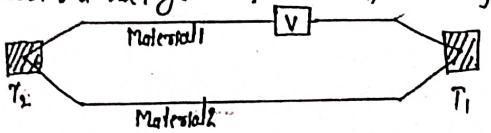
Bi-metallic thermometer:

- A metal tends to undergo a volumetric dimensional change according to the change in temperature.
- Different metal have different co-efficient of thermal expansion for different temperature. The rate of volume change depends on this thermal expansion co-efficient



Thermo-couples:

A thermo-couple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one spot differs from the reference temp at other parts of the circuit.



Principle: Thermocouples are based on the principle that two wishes made of dissimilar materials connected at either end will generate a potential between the two ends that is a function of the materials and temp. difference between the two ends (also called seebeck effect). T_1 = known temp, V = Voltmeter.
T_2 = unknown temp

Q.1 Compare the different temperature scales?

Ans ① Kelvin
② degree celcius
③ degree fahrenheit

Water freezes at

255.37K — 0°C — 0°F

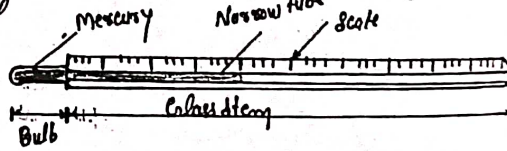
Q.2 Explain different types of temperature measurement discuss construction and working of thermocouple.

Ans: Temperature measuring Devices :-

1) Liquid in glass thermometer
2) Bimetallic thermometer
3) Thermocouples

1) Liquid in glass thermometer: The basis of the thermom operation is the thermal expansion of a working fluid (me

The volume of mercury changes slightly



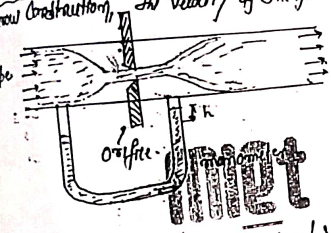
with temp. The small change in volume causing the m mercury column a relatively long way up the tube. Th above the mercury may be filled with nitrogen or it at less than atmospheric pressure, a partial vacuum.

Q. Discuss the types of flow meters and explain any of them?

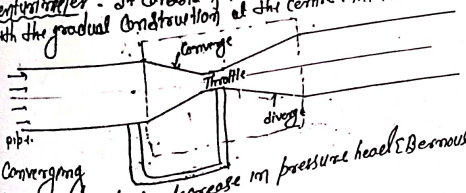
To measure the flow of fluid (water) in m³/sec/litre/sec/per minute. Ips to through any pipe.

Types: ① Orifice meter
② Venturi meter

Orifice meters: When fluid stream is suddenly allowed to pass through a narrow construction, the velocity of the fluid at orifice meter increases as compared to velocity of the fluid in the upstream. The decreasing the pressure head (Bernoulli's theorem). The difference of pressure head may be measured by manometer.



② Venturimeter: It consists of two tapered sections in the pipelines with the gradual construction at the centre. The increase in velocity at Converging section, resultant to decrease in pressure head (Bernoulli's theorem).

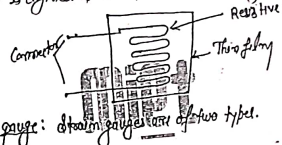


Q.1 What is strain gauge? Explain different methods to calculate strain?

Ans: Strain gauge: Strain gauge is sensor whose resistance varies with applied force. It converts force, pressure, tension, weight, etc. into a change in electrical resistance which can then be measured.

When external forces are applied to a stationary object, stress and strain are result.

Stress is defined as the object's internal resisting forces and strain is defined as the displacement and deformation that occur.

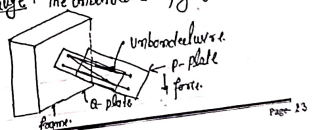


Types of strain gauge: Strain gauge are of two types.

① Bonded strain gauge
② unbonded strain gauge

① Bonded strain gauge: This types of strain gauge is bonded directly or to the surface of the specimen being tested with thin layer of adhesive cement.

② Unbonded strain gauge: The unbonded strain gauge consist of a



Q.2 What are different methods to Calculate force?

Ans: A measure of the unknown force may be accomplished by the method incorporating the following principles:

→ Balancing the force against a known gravitational force on a standard mass.

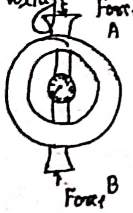
→ Translating the force to a fluid pressure and then measuring the resulting pressure.

→ Applying the force to some elastic member and then measuring the resulting deflection.

Types of force measuring devices:

1. Proving Ring
2. Spring Scale
3. Load cell

① Proving Ring: A ring used for calibrating tensile testing machines. It works on the principle of LVDT which sense the displacement cause by the force resulting in proportional voltage. When the forces are applied through the integral external force bosses A and B, the diameter of ring changes depending upon the application which known as ring deflection.

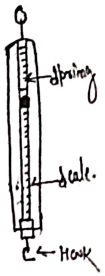


Spring Scale.

As shown in figure spring scale, the unknown weight is suspended from a hook. The deflection of spring with respect to weight is recorded on the scale in terms of the weight.

$F = K \cdot x$ ← deflection

↓ Load. ↳ stiffness of spring



- Load Cell

A load cell is a device that convert a force or

into a measurable output

Load cell is a force transducer, which uti

deflection of any elastic member as a primary sen

device and strain gauge as a secondary transducer

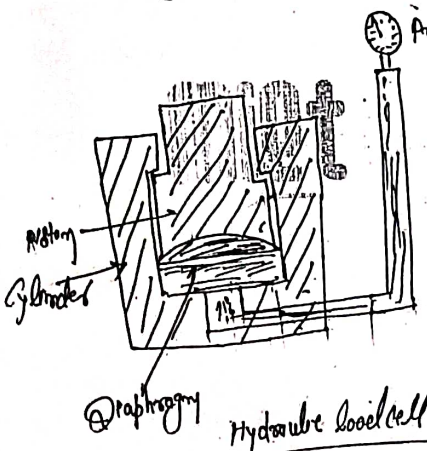
Types of load cell:

- → Hydraulic load cell
- → Pneumatic load cell
- — strain gauge load cell
- → piezo-electric load cell.

Hydraulic load cell:

The input force is applied to the piston via loading platform. piston moves down ward and deflects the diaphragm. The deflection in diaphragm increases the pressure in the fluid chamber.

The increase in pressure of fluid is a function input force which is to be measured. It is indicated by a suitable pressure gauge calibrated in terms of forces



Hydraulic load cell

Q.3 Explain with a neat sketch. Determine force using a load cell?

Ans: Refer to page No 25 & 26

Lecture - 36

Torque: It is defined as a twisting force that tends to cause rotation.

Torque may be computed by measuring the force at a known radius r.

$T = F \cdot r$ F: force (N)

r: Radius from pivot point (m)

Dynamometer:

A dynamometer is a device that is used to measure torque and the rotational speed of a machine.

Types: Dynamometer are of two types

① power absorption dynamometer

② power Transmission dynamometer.

① Power absorption dynamometer:

It is measure and absorbed the power output of the engine to which they are coupled. It dissipated heat

e.g. of power absorption dynamometer

- Prony brake dynamometer
- Rope " "
- Eddy current "
- Hydraulic dynamometer

Power Transmission dynamometer :

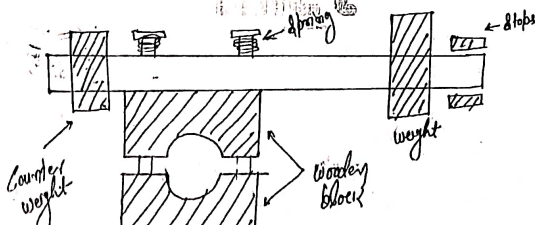
It is power transmitted to the load coupled to the engine after. It is indicated on same scale

These are called torquemeter. The power transmission dynamometer measuring torque through sensors, usually strain gauge that are attached to rotating shaft

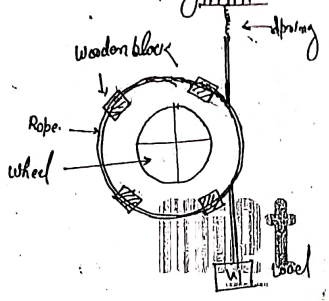
- Rotary brake dynamometer :

It has two wooden blocks that are placed on a pully which is fixed on the shaft of the engine whose power is measured.

The wooden blocks are clamped together with two set of bolt and nut.



- Rope Brake dynamometer It consists of some turns of rope that is wound around the rotating drum fixed on the output shaft. One end of rope is connected to the loading and other end is to spring balance.



Q. 1 what are the different methods of calculating torque?

Ans: Refer page No 27, 28, 29

Lecture : 87

Concept of accuracy and precision

you will be able to

accuracy & precision) .

Accuracy : Accuracy is the ability of the accurate value Conformity

Accuracy is a measure of nearness

Precision : It refers to how closely agree with each other & Repeatabi

Precision is a measure of

Resolution The resolution of a mea smallest yet to distinguish differen resolution of an instrument has no measurement.

Lecture : 27

Concept of accuracy and Precision

You will be able to understand difference between accuracy & precision.

Accuracy: Accuracy is the ability of the instrument to measure the accurate value [Conformity]

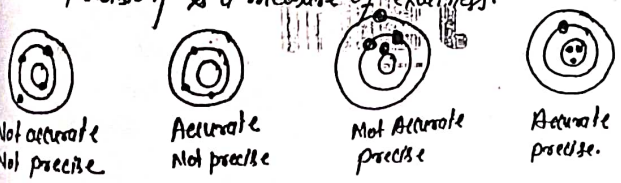
or

Accuracy as a measure of rightness

Precision: It refers to how closely individual measurement agree with each other [Repeatability]

or

Precision as a measure of exactness.



Resolution: The resolution of a measurement system is the smallest yet to distinguish different in values. The specified resolution of an instrument has no relation to the accuracy of measurement.

Q.1 Differentiate between accuracy and precision?

Soln: Refer to page No 30.

Q.2. Write the short notes on measurement resolution and accuracy

Soln: Refer to page No 31

Q.3 Explain the differentiate between accuracy and precision in an instrument

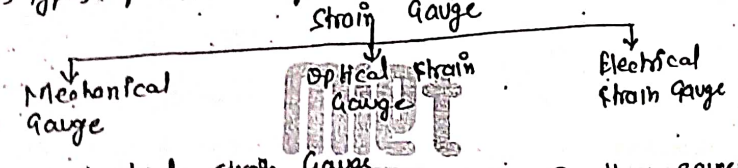
Ans

Basis for Comparison	Accuracy	Precision
Meaning	Accuracy refer to the level of agreement b/w the actual measurement & the absolute measurement	Precision implies the level of variation that lies in the value of several measurement
Represents	How closely result agree with the standard value?	How closely the results agree with one another
Degree	Degree of Conformity	Degree of reproducibility
Factors	Single factor	multiple factor
Measure of	Statical bias	statistical variability
Concerned with	Systematic Error	Random Error.

Q.1 What is strain gauge? Explain different methods to calculate strain.

When a body or component subjected to different loads i.e tensile, compressive & shear, body experience change in dimension. The ratio of change in dimension to original dimension is known as strain. The transducer used for measurement of strain are generally refferred as strain gauge. We usually calculate longitudinal (axial) strain because all other type of strain can be can calculated by using por elastic constants (μ, E, G & K)

→ Types of Strain Gauges



(I) Mechanical strain Gauge - These are also called extensometer. In these gauges change in length is magnified using levers or gears. They are generally large in size hence suitable for use only where sufficient area is available.

Example- Huggenburger extensometer - Lever system is used for magnification of small strain.

(II) Optical strain Gauge - They are similar to mechanical gauges the only difference is magnification done is by multiple reflector using mirrors or prism they are high accuracy.

Example- Martin's mirror type extensometer.

(III) Electrical Strain Gauge - These are based on change of charge in resistance, inductance or capacitance. Gauges based on change in resistance are frequently used. for many metals used as strain gauge the following correlation is applicable.

$$F = 1 + 2\mu$$

F = Gauge factor = fraction change in resistance / longitudinal strain

μ = poisson's Ratio.

$$F = \frac{\delta R/R}{\delta L/L}$$

→ electrical strain gauges further sub categorized into
- bonded strain gauges
- Unbonded strain gauges

based on method of fabrication

(I) Bonded Strain Gauges - they are bonded directly the surface of specimen with the thin layer of adhesive cement. This adhesive cement serves the purpose:
- transfer the strain from specimen to gauge wires.
- acts as electrical insulator.

bonded strain gauge basically consist of grid of resistance wire of 25μm diameter.

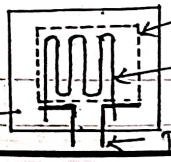


Fig: Flat grid type strain Gauge.

In flat grid type, sensing wire (strain gauge wire) is wound as shown in figure. This grid is bonded to a backing material (paper, epoxy) using adhesive. The adhesive hold the wire to base firmly to allow good of strain from base to wires. Wire grid plane should be very close to specimen surface so as to achieve max. transfer of strain.

- Unbonded metal wire strain gauge: These type of gauges doesn't having backing material, so strain is transferred to the resistance wire directly. Wires of tungsten alloy are used for these gauges. Wires are wound blw two insulated pin one of which is fixed in a stationary frame while the other on movable frame.

- The gauge employs a set of unbonded metal wires which are connected to wheatstone bridge. When forces acts on movable frame, change in length cause change in resistance of wire this leads to change in voltage of wheatstone bridge. this voltage is calibrated in terms of strain.

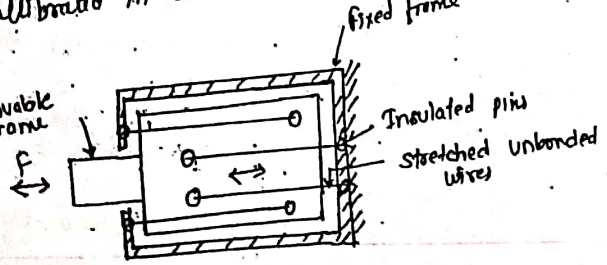


Fig: Unbonded strain gauges.

Bourdon Gauge:

Bourdon gauge is used to measure fluid pressure. The pressure responsive element of bourdon gauge consists of metal tube (called bourdon tube / spring) which is initially oval in cross-section & bent to form a circular segment of approximately 200- 300 degrees. This tube 'A' is fixed at one end 'A' while other end 'B' is free to move & close at that end. When the pressure more than atmospheric pressure is applied to the hollow tube, its cross-section tends to become circular. This makes the tube to straighten itself out with a consequent increase in its radius of curvature.

This deflection of tube is small & for small pressure this tube deflection is difficult to measure. To amplify the tube deflection various linkages are used like spring loaded linkages, sector-pinion linkage, LVDT etc.

→ Bourdon tube shapes & configuration

The C-type bourdon tube has a small tip travel & this necessitates amplication by a lever, quadrant, pinion arrangement. Although, increased sensitivity can be obtained by using long length of tubing in the form of a helix & a flat spiral.

Spiral tubing works on same effect as would be given by C-tubes. But the deflection & tip is sufficient enough to indicate directly against a calibrated dial. Likewise, increased no. of turns in helical bourdon

makes it possible to obtain a greater angle of uncoil. Spiral & helical tubes are generally used as they eliminate the use of multiplication linkage b/w pressure element & recording arm.

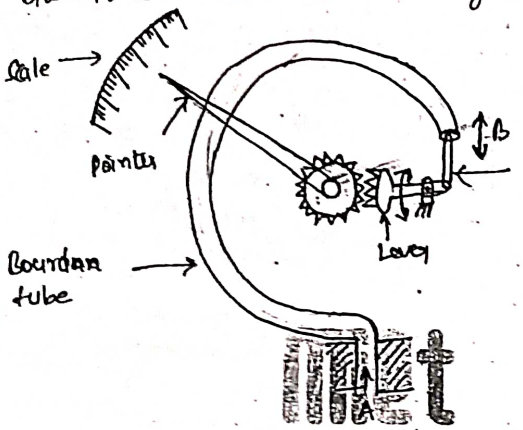
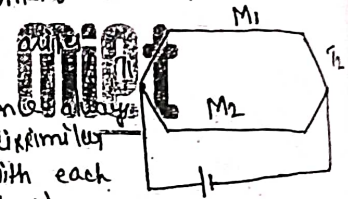


Fig: Bourdon tube Pressure Gauge.

Advantages:- Low cost & simple in construction.
- capability to measure gauge, absolute, differential pressures.
- Calibration is easy.
- Work in several ranges (high to low pressure)

Limitation: due to linkages, losses are more.
- amplification is required.
- Calibration required due to shock & vibration

Thermocouples: Thermocouple is a device used to measure the temperature. When two conductors of dissimilar metals M_1 & M_2 are joined together to form a loop & two unequal temperatures T_1 & T_2 are imposed at the two interface, an electric current flows through the loop. The magnitude of current is directly related to material of conductor M_1 & M_2 and temperature difference $(T_1 - T_2)$ b/w junction. For the purpose of measurement, temp at one junction is known & other junction are put in contact with unknown temp. the value of current flowing in circuit give the value of unknown temp.



Thermo-electric effect arises in two way:
- potential difference always exists b/w two dissimilar metals in contact with each other (Peltier effect).
- a potential gradient exists even in a single conductor having a temp. gradient (thompson effect)

Thermocouple Materials:
(i) Thermocouple should have a long-life so that cost associated with replacement of material is reduced.
(ii) Material should withstand high & fluctuating temperatures

(i) materials must be such that successive batches can produced with same of thermo-electric characteristics.

(iv) Emf produced per degree of temp. change must be detected easily.

(2) → Thermocouples are further categorized as:

(i) Base metal thermocouples - pure metal or alloys of iron, Cu & Ni are used.
- measuring temp is lower than 1375°C.

(ii) Rare metal thermocouples -
- alloys of platinum & rhodium for temp. upto 1725°C.
- alloys of tungsten, rhodium & molybdenum for temp. upto 2815°C.

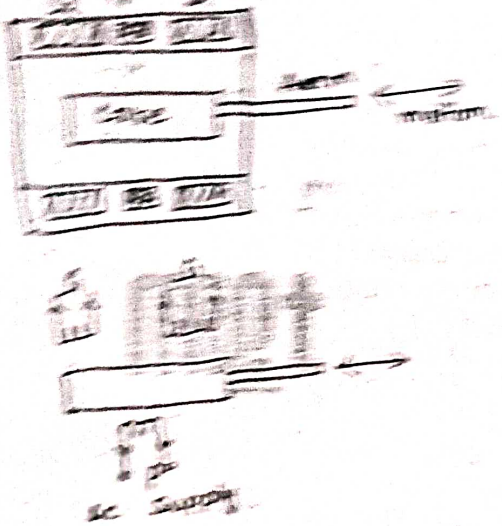
(2) Bimetallic thermometer - It consist of two different metallic strip of diffrent thermal expansion coefficient bonded together by welding, in the form of cantilever beam, a spiral or helix. With rise or change in temperature, the strip bends according to their expansion coefficient (α). This deflection can be calibrated to temp. change. Usually, a long bimetallic strip is so coiled in the form of spiral or helix to improve the sensitivity of the instrument. Thus, by coiling the strip in the form of spiral or helix, it becomes possible to obtain sufficient rotation at free end without using gears or other linkages.

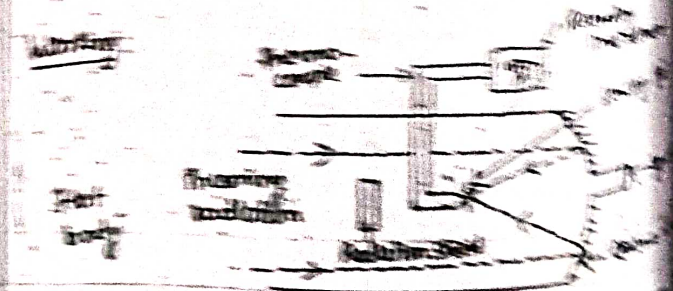
LVDT:- LVDT stands for Linear Variable differential transformer. It is used to measure linear displacements. LVDT is widely used because of high accuracy & reliability. It consists of one primary coil & two secondary coil (S_1 & S_2) with soft iron magnetic core which is free to move inside the coils. Two secondary coils are connected in series opposition. This implies that two secondary winding are identical symmetrically placed and are connected in phase opposition such that emf induced in them are opposite to each other. The net output of LVDT is the difference b/w voltage of two secondary windings.

$$E_0 = E_1 - E_2$$

When core is exactly in between to two secondary windings, the voltage across them (E_1 & E_2) are equal in magnitude. Hence, output is zero. But when the position of core gets displaced from its central position, then voltage induced in one secondary coil increases compare to other and hence net output (E_0) is proportional to displacement of soft iron core.

$$E_0 \propto \text{displacement}$$

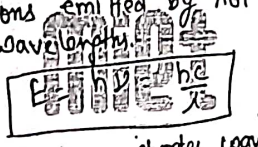




It is basically thermocouple instrument placed in black tube. One junction of thermo-couple has sensing disc. Radiation coming from hot body are made to focus on disc by using concave mirror which can be adjusted by rack & pinion arrangement. This radiation causes rise in temperature at this junction and emf will be induced which can be read by recording element. This recording can also be calibrated in terms of temperature.

2) Optical Pyrometer: It can be used to measure temperature in the range of 850°C - 2500°C

Principle: According to planck's law, energy levels in the radiations emitted by hot body are distributed in different wavelengths.



High energy will have shorter wavelengths & vice-versa colours are dependent of wavelengths. hence we can measure brightness of light of a given colour emitted by hot source, we can estimate its temperature

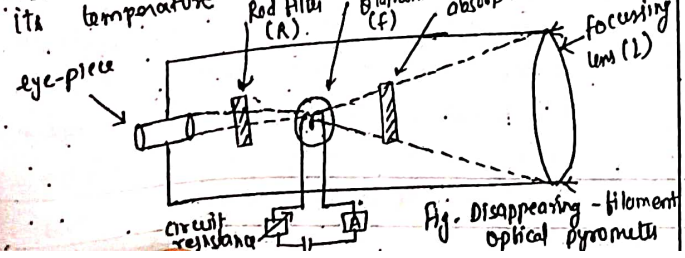


Fig. Disappearing - filament optical pyrometer

Working: Radiation from target surface are focussed by an objective lens (L) on filament (f) of electric light bulb. Eye piece (E) is also adjusted until the filament is in sharp focus & under these conditions the filament is seen superimposed on image of target surface. A red filter (R) is placed b/w eye-piece and filament & allows only narrowband of wavelength 0.65 μ to pass through it. Matching of brightness of lamp filament with that of target surface is achieved by adjusting current by changing the value of circuit resistance. Value of resistance is calibrated in terms of target temp.

Three different conditions of filament as sighted through eyepiece are:

(i) filament is colder than target surface, then it appears as dark wire against light colour background.

(ii) filament hotter than object, it appear brighter than target surface.

Mechatronics :—

Mechatronics is a concept originated in Japan in 1969. This term was coined by the Japanese scientist Yoshikaza. It is a multidisciplinary engineering design approach.

Definition of Mechatronics →

Mechatronics can be defined as " a combination of Mechanical, Electrical, Electronics, Computer & Control Engineering in order to design and manufacture useful products.

Scope — Mechatronics has large scope for engineers from all branches of engineering. For example;

→ A mechanical engineer can work in the areas like Robotics, Industrial Automation, CAD, CAM, CIM, Product Design & Development, etc.

→ A computer engineer can work in the areas like Artificial Intelligence (AI), Simulation, etc.

→ An Electronics engineer can seek job in the areas like VLSI Design, Robotics, Avionics, etc.

→ An Electrical engineer can work in the areas like Inspection, Robotics, as System Engineer, etc.

→ An Aerospace Engineer works a lot on Mechatronic systems, can seek jobs in Avionics, etc.

Evolution of Mechatronics :—

First Stage :— 1969—1979 :—

During this era, technologies used in Mechatronics developed individually & rather independently of each other.

Second Stage :— 1980—1989 :—

During this era, a synergic* integration of different technologies started taking place. A notable one is opto-electronics, which is an integration of optics and electronics. The concept of hardware co-design also started in this era.

Third Stage :— 1990 onwards :—

This era is considered as start of 'Mechatronics'. The most notable aspect of this stage is more integration of different engineering disciplines, increased use of computational intelligence in mechatronic products and systems. Another development in this era is the introduction of microactuators & micro-sensors and thereby developping the concept of "micromechatronics".

* Synergic combination of multiple disciplines is the phenomenon where additional benefits are achieved that are not achievable by the separate use of any individual discipline of engineering.

Advantages of Mechatronics :-

1. It provides rapid manufacturing operations.
2. It helps in optimizing performance & quality.
3. It provides high degree of flexibilities in operations & processes.
4. It enhances plant utilization.
5. Mechatronic products are better than those obtained from traditional methods.
6. Mechatronics results in greater productivity.
7. Mechatronics results in greater (High) precision & High accuracy.
8. Mechatronics results in better process planning & control.

Objectives of Mechatronics :-

The primary objective of Mechatronics is to integrate the mechanical systems with electrical, electronics & computer systems to make useful products & systems.

The other objectives include :-

- → Customer satisfaction & comfort.
- → To improve existing products by better design.
- → To improve overall efficiency of the system.
- → To achieve higher accuracy & precision, etc.

Disadvantages (Limitations) of Mechatronics :-

There are some disadvantages also associated with mechatronic systems :-

1. Mechatronics requires knowledge of different disciplines.
2. The design cannot be finalized easily and its is usually complex.
3. Mechatronic systems require highly skilled manpower.
4. Initial costs of the systems are usually high.
5. Mechatronic systems require more parts than other systems and thus involve a greater risk of component failure.
6. Repairing and maintainance of mechatronic system is costly.

Comparison between Traditional & Mechatronic Design Approach :-

Traditional Design Approach	Mchatronic Design Approach
1. Budky System	1. Compact System
2. It is a process involving interactions b/w a few disciplines of engineering.	2. It is based on integration of various emerging technologies.
3. The control is accomplished manually.	3. Usually a microprocessor is used as controller.
4. Synchronization is mechanical.	4. Synchronization is electronic.
5. Less accurate	5. More accurate
6. Low cost	6. High cost
7. Less flexible	7. More flexible
8. Heavy Structures	8. Lighter structures

Industrial Applications of Mechatronics →

Mechatronics is extensively used in modern industries. Specifically, automobile industry, bio-medical [illegible] industry and aviation industry have been benefited through mechatronics. The application of mechatronics in these industries have created specialized domains of :-

(1). Autotronics
(2). Bionics
(3). Avionics

→ Autotronics is the combination of Automobile Engineering & Mechatronics; resulting in more comfortable, safe, fuel efficient and less-polluting vehicles.

→ Bionics involves integration of Biomedical/Biological Sciences and Mechatronics; resulting in enhanced functionality of biomedical equipments/machines, better control for operators, etc.

→ Avionics is the integration of Aviation and Mechatronics, widely applicable in aerospace

A few other applications of Mechatronics are:—

1. Washing Machine
2. Air Conditioner
3. Computer Disk Drive
4. Heat Seeking Missiles
5. Elevators
6. Escalators
7. Automated Crane Systems

Key Elements of a Mechatronic System :—

(Components of a Mechatronic System) :—

(1). Physical System being controlled :—

The system being controlled may be mechanical, fluidic, chemical, thermal or electrical.

(2). Sensors :—

Sensors are the eyes and ears of the controller. They detects the state of system parameters & send the signal to the controller.

(3). Controller :—

The controller is the brain of the mechatronic system. It reads the input signal, compares them to the required states & sends the output signal to the actuators.

(4). Actuators :—

Actuators control the physical system by providing relevant physical input like force or torque. They can be mechanical, hydraulic, pneumatic or electrical as per the situation.

Autotronics :-

Integration of Automobile Engineering & Mechatronics is called Autotronics. A few examples of autotronic systems are :- (Applications of Autotronics) :-

1. ECU (Engine Control Unit.)
2. Windscreen Wiper Mechanism
3. Digital speedometer & odometer.
4. ABS (Antilock Braking System)
5. Air bag deployment system
6. Automatic headlamps
7. Automatic cooling system for passengers
8. Transmission system

Brief Explanation of a few autotronic systems :-

1. ECU :- It is Engine Control unit, that consists of an electronic control on various actuators to ensure optimal engine performance.

2. Windscreen Wiper Mechanism :-

It is a device used to clear rain water from the front glass of the vehicles. A stepper motor with microprocessor is used to oscillate the wiper back & forth in this mechanism.

3. Anti Lock Braking System (ABS) →

Problem without ABS :-

Suppose the brakes are suddenly applied with
This results in locking up of wheels (
and the vehicle starts skidding. This
increased stopping distance, that may
accident.

ABS solves the problem of Skidding :-

ABS is an automobile safety system th
the wheels on a vehicle to maintain
contact with the road according to dri
while braking, preventing the wheels f
up. ABS offers improved vehicle
decreases the stopping distances on
slippery surfaces.

ABS typically includes a central ele
control unit, four wheel speed sens
and at least two hydraulic valves
the brake hydraulics. The ECU
monitors the rotational speed of

If it detects a wheel rotating significantly slower than the others; which is a condition of impending wheel lock; it actuates the valves to reduces hydraulic pressure to the brake at the affected wheel, thereby reducing the braking force on the wheel. The wheel then turns in the desired speed.

Conversely, if the ECU detects a wheel turning significantly faster than the others, it actuates the valves to increase hydraulic pressure to the brake at the affected wheel, thereby increasing the braking force to bring its rotational speed down, in the desired range.

ECU is programmed to disregard differences in wheel rotation speeds below a critical threshold, because when the car is turning, the two wheels towards the centre of the curve turn slower than the other two.

If a fault is developped in any part of the ABS, usually a warning light is illuminated on the vehicle pannel, and the ABS will be disabled untill the fault is rectified.

4. Air Bag Depolyment System :-

An Air Bag is a vehicle safety device. It is a type of occupant restaint system that consists of a flexible fabric bag, also known as an airbag cushion. The airbag module is designed to inflate rapidly then quickly deflate during a collision with another object. The purpose of the airbag is to provide protection to the occupants. Air Bag provides an energy-absorbing surface between the occupants & vehicle parts like windscreen, Structural body, instumental panel, Steering wheel, etc.

Time taken in deploying an Air-Bag :-

Typically, the decision to deploy an airbag in a frontal clash is made (by the ACU) within 15 to 30 milliseconds after the onset of the crash and both — the driver & passenger airbags are fully inflated within approximately 60 to 80 milliseconds after the first moment of vehicle contact.

Bionics →

Bionics is the combination (integration) of Biology and Mechatronics.

Advantages of Bionics :-

1. Better Control & functionality of biomedical equipments.
2. Better mobility & easy navigation facility for biomedical operators.
3. Accurate & fast diagnosis, etc.

Applications of Bionics :- A few notable applications

1. Photogynamic Therapy for Cancer treatment
2. Photodynamic therapy for several purposes
3. Biostructures (nanoscale bio-structures)
4. Bionic Limbs (Artificial Hands/Legs)
5. Biosensing
6. DNA sensing.

A few examples of Bionics-based processes :-

Glucose Detection :-

Detection of glucose levels in blood is a good example of biosensing. Diabetic patients cannot control their insulin level if the level of blood glucose fluctuates tremendously. If the level gets too high or too low, their condition can become life-threatening. Such patients must actually draw blood on daily basis or even more often to monitor blood sugar level.

The optical conduction method & molecular recognition method are not compatible with an "implantable" simple device that could automatically show/sense the glucose level in the body.

This problem has been resolved by CGM (Continuous Glucose monitoring), that works through a tiny sensor inserted under your skin, usually on your belly or arm to measure your interstitial glucose level, which is the glucose

found between the cells. The sensor tests glucose every few minutes. A transmitter wirelessly sends the information to a monitor. The monitor may be a part of an insulin pump or a separate device, which you (patient) might carry in a pocket or purse.

An alarm can also be a part of CGM, triggering sound in case of sudden rise or drop in blood sugar level.

Currently, one CGM model is approved for treatment, the Dexcom G5 Mobile.

The CGM sensor is to be replaced every 3 to 7 days, depending on the model.

Avionics → Avionics is the integration of Aviation & Mechatronics. The major applications of Avionics are as follows :-

Applications of Avionics :-

1. Cockpit Instrumentation
2. Aircraft Safety Devices
3. Aircraft Guidance & Control
4. Air Traffic Control (ATC)
5. Aircraft Engine Control
6. Microsatellites, etc.

Cockpit Instrumentation —

A cockpit or flight deck is the area, usually near the front of an aircraft, from which a pilot controls the aircraft. Various instruments available in cockpit are:-

(i) Pitot Tube — It is used to measure the stagnation pressure of air, which is used to determine the airspeed of the aircraft; which is the speed of an aircraft relative to the air.

(ii) Aircraft Altimeters → The altimeter shows the live altitude of aircraft (above sea-level). For this purpose, a bellow or a piezoresistive silicon sensor are mostly used.

a). Using a bellow → As the aircraft ascends, the static pressure drops, resulting in the expansion of an aneroid capsule (bellow) placed inside the altimeter, causing the altimeter to indicate a higher altitude. The opposite effect occurs when descending.

b). Using a piezoresistive sensor → Piezoresistive sensor changes resistivity when pressure acting on it changes.

When the aircraft ascends, the resistivity of the piezoresistive silicon sensor placed inside the altimeter changes, causing a change in the resistance. An output electrical signal proportional to the pressure change is obtained through a transducer; which is used to calculate (cal) in altitude of the aircraft.

(iii) Vertical Speed Indicator (VSI) —

VSI indicates the rate of rise or drop in the ~~ramp altitude~~ of the aircraft in feet per minute. Newer designs directly measure the static pressure of the atmospheric air using a pressure sensor to note the changes in altitude, without measuring any A piezoresistive silicon sensor is mostly used for this purpose.

(iv) Air-data Computers —

The Air-data computers centralize the computation air data from a number of inputs, like Static Total pressure, Air stagnation Temperature, Attack, etc.

(v) Air-Speed Indicators — It shows the speed of aircraft relative to the air

(vi) Angle of Attack Transducer — It measures the angle between the velocity vector of the aircraft some reference axis, such as chord of an

Aircraft Guidance & Control —

To guide & control an aircraft, three functions are required :-

1). Navigation 2). Guidance 3). Steering

1. Navigation — The determination of position & direction of an aircraft is navigation. Avionics provides the use of satellite-based systems such as GPS and WAAS, ground-based systems such as VOR and LORAN, or any combination thereof.

2. Guidance — It determines & corrects the deviation from the indicated path. The aircraft guiding system measures position, velocity, acceleration & predicts the destination, determines a preferred path to correct the error & controls the forces to change the path from steering instructions. All of these functions can be automated.

3. Steering → Steering is used to select a proper series of changes in the path. Steering system design is complex, it depends mainly on the weight of the aircraft.

Air Traffic Control —

Air traffic control is a service provided by ground-based controllers, who direct aircrafts on the ground and also during the flights. ATC staff can provide advisory services to pilots in controlled / non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, to organize & expedite the flow of air traffic; and to provide information & other supports to pilots. In some countries, ATC is operated by the military.

Position reporting by the pilot to the Air Traffic Controller over a voice radio link is the basic source of Air traffic control position data. The ground controller can ascertain the aircraft location independently using radars. Another important task of ATC is → MSAW. Minimum Safe Altitude Warning (MSAW) may be issued to pilots, if the aircraft is appearing to be flying too low.

Sensor —

Senor is the first element which is directly coupled to the system under study for measurement purpose. A Sensor may be defined as "an element that senses a variation in input energy to produce a proportional variation in another or same form of energy is called a sensor."

Transducer →

Transducer is a device which affects the transformation of information from one form of energy to another. It uses a transduction principle to convert a specified measurand into usable output.

Types of Sensors →

→ There are a lot of types of sensors based on measurand —

(1). Temperature Sensor
(2). Position Sensor
(3). Accelerameter
(4). Displacement Sensor
(5). Pressure Sensor
(6). Light Sensor
(7). Force Sensor
(8). Humidity Sensor
(9). Ultrasonic Sensor
(10). Flow & Level sensor, etc.

Types of Sensors based on detection —

(1). Touch Sensor
(2). Colour Sensor
(3). Proximity Sensor
(4). IR Sensor
(5). Alcohol Sensor
(6). Smoke Sensor
, etc

Sensors may also be classified as Internal sensors & External sensors —

Internal Sensors →

Internal sensors are for internal feedback control within a system. They are used to monitor & control the various elements in the mechatronic system.

Examples of Internal sensors are :—

1. Potentiometers
2. Tachometers
3. Resolvers
4. Optical encoders
5. Hall effect sensors
6. Moire's fringes

External sensors →

These are peripheral devices used in mechatronic systems. External sensors are used when we want to control or measure various parameters affecting the system.

Examples of External sensors are :—

1. Proximity Sensors
2. Range Sensors
3. Force Sensors
4. Tactile Sensors
5. Machine Vision Sensors

Types of Transducers →

Based on quantity to be measured →

1. Temperature Transducer - (Example - Thermocouple)
2. Pressure Transducer - (Example - Piezometer)
3. Displacement Transducer - (Example - LVDT) etc.

Based on principle of operation →

1. Capacitive
2. Resistive
3. Inductive
4. Photoelectric
5. Chemical

Based on need of an external power source →

1. Active Transducer
2. Passive Transducer

Active Transducers :- Those transducers, which do not require external power source for their operations are known as active transducers.
Examples :- Thermocouple, Thermometer, etc.

Passive Transducers :- Those transducers, which require an external power source for their operations are known as passive transducers.
Examples :- Strain Gauge, Thermistors, etc.

Performance characteristics of Sensors & Transducers →

These are of two types :-
(i) Static characteristics
(ii) Dynamic characteristics

Static characteristics → Static Performance Characteristics is the criteria considered when the system is used to measure a quantity that is either constant or vary slowly with time. Static performance characteristic parameters define the quality of measurement, they are:-

(1). Accuracy
(2). Precision
(3). Sensitivity
(4). Threshold
(5). Dead zone
(6). Error
(7). Resolution
(8). Hysteresis
(9). Hysteresis Error
(10). Drift

Dynamic Characteristics → The set of criteria, which are defined on the basis of Input-Output relation when the input (measurand) changes rapidly with time, are called dynamic characteristics.
The main dynamic characteristics of an instrument are :-

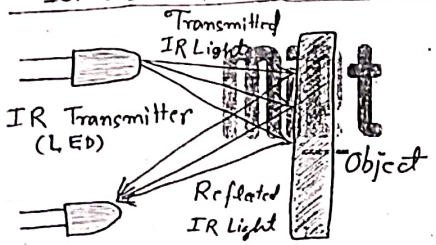
(1). Speed of Response
(2). Lag
(3). Fidelity
(4). Dynamic Error

Proximity Sensors —

Proximity sensors are a type of position sensors & they are used to trace when an object has moved within a particular critical distance from it. They can be of many types like — Electromagnetic proximity sensor; Eddy current proximity sensor; magnetic proximity sensor, Doppler effect proximity sensor, etc.

Infrared Proximity Sensor —

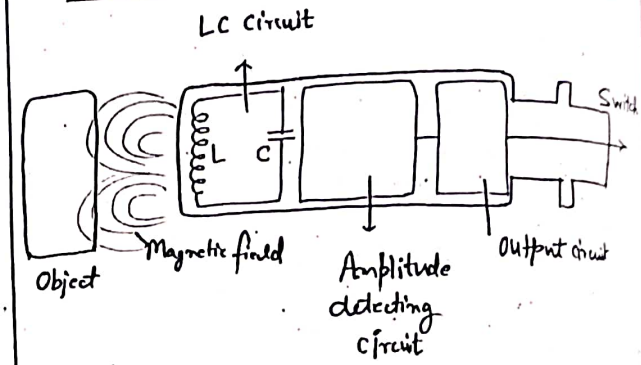
It consists of an IR emitter & an IR reciever.



IR Reciever indicates the proximity of an object by recieving the reflected IR Light.

Eddy Current Proximity Sensor —

Eddy current proximity sensors are used to detect conductive-material object in proximity. They comprise of a coil, L-C circuit, detector & a triggering switch.



Eddy Current Proximity Sensor

An alternating current is passed through the coil, because of which an alternating magnetic field is generated. If a conducting object comes close to the coil, then a voltage difference is induced in the object, which produces the eddy currents (currents in following in shape of 'eddy') (A rotary or whirling current) to oppose the magnetic field responsible for their generation. These eddy currents produce their own magnetic field to distort the original magnetic field of the coil, hence changing the amplitude of the current in the coil. This change in amplitude is detected & the switch is triggered.

Kinematic Links —

A Kinematic link is a resistant* body that constitutes a part of the machine, connecting other parts which have motion relative to it.

Examples :— Piston Rod, crankshaft, CAM, follower, etc.

* Resistant Bodies — These bodies are undeformable for the purpose they are serving, in other words they act as a rigid Body in that particular service.

for example.- A bolt is a resistant body, b'coz it doesn't undergo deformation when Shear force is applied on it.

* All rigid bodies are resistant bodies but reverse is not true.

Kinematic Pair →

Kinematic pair is defined as the two links (or) elements of a machine having definite relative motion between them; i.e. motion constrained in definite direction. Examples :-

(i) CAM-follower (ii) Piston-cylinder, etc.

Kinematic chain → When 2 or more Kinematic pairs are joined together, they form a Kinematic chain. Example :- Four Bar Mechanism.

Kinematic Pairs may be Sliding, turning, rolling, screw or spherical as shown in figures :-

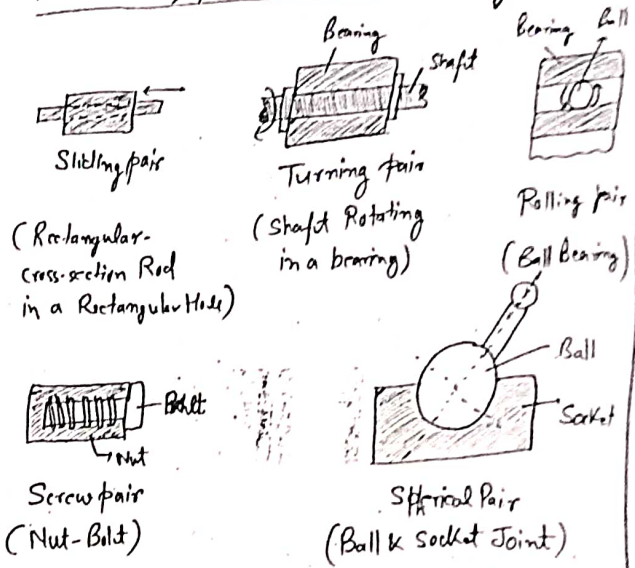
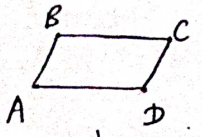


figure: Various types of Kinematic Pairs

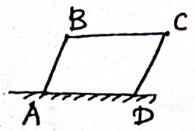
Inversion of a mechanism →

If we fix any one link of a ~~one~~ Kinematic Chain, then it is called a mechanism. And different inversions are obtained by fixing different links of the Kinematic chain. So Inversions are

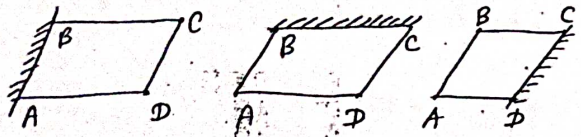
.... basically the various types of a particular mechanism.



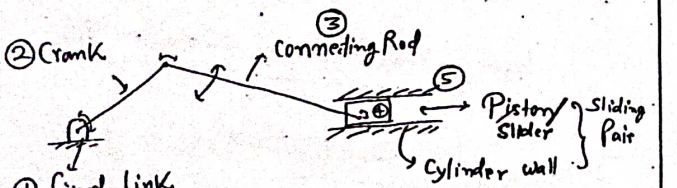
four-bar chain



four-bar mechanism



Other inversions of 4-Bar mechanism



Here 1-2, 2-3, 3-4 are turning pairs.

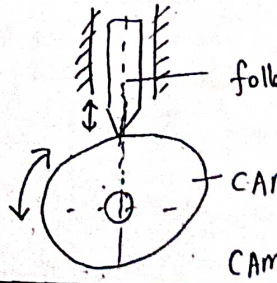
Piston-cylinder pair & [Slider-crank mechanism]

CAMS →

A cam is a rotating or sliding link used to transmit motion to a follower. A rotating cam is of many types like plate or disc cam, cylindrical cam, & A sliding cam is usually a wedge cam. Both rotating & sliding cams provide an oscillatory motion to the follower working as a pair in the CAM-follower assembly; alongwith the CAM.

Mostly CAMS are used to convert rotary motion into oscillatory motion.

CAM is the driver member in CAM-follower pair & follower is the driven member in the CAM-follower pair.



CAM-follower pair

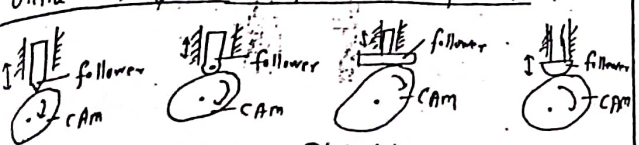
Various types of CAMS —

1. Wedge cam.
2. Plate cam, also known as radial cam or disc cam.
3. Cylindrical cam.

Wedge CAM | Plate CAM | Cylindrical CAM

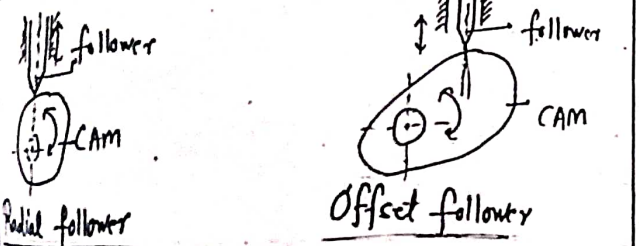
Various types of followers —

(A) On the basis of contact b/w CAM & follower —



Knife edge follower | Roller follower | Plate type follower | Spherical follower

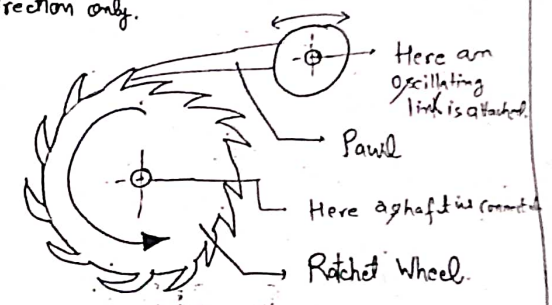
(B) On the basis of line of oscillation of follower —



Radial follower | Offset follower

Train Ratchet Mechanism —

The train-ratchet mechanism is an asymmetric mechanism that allows something to turn in one direction only.



This mechanism consists of a pawl attached to the oscillating link. This pawl has a relative motion with respect to the ratchet wheel having teeth on its periphery is a shape to allow rotation of wheel only in one direction. The ratchet wheel is connected to a shaft.

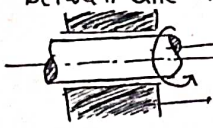
This mechanism is used to produce an intermittent output motion from an oscillating input motion.

Bearings :-

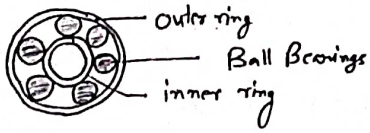
A bearing is a device which supports, guides & restrains motion between two mating parts of a machine to provide the desired motion. They also reduce the friction between the mating parts.

Types of Bearings — Bearings may be classified into 2 categories :-

(i) **Sliding Contact Bearings** —
A type of bearing, where relative sliding is seen between the mating parts. Example :-



(ii) **Rolling Contact Bearings** —
A type of bearing, where there is rolling between the mating parts. Example :-

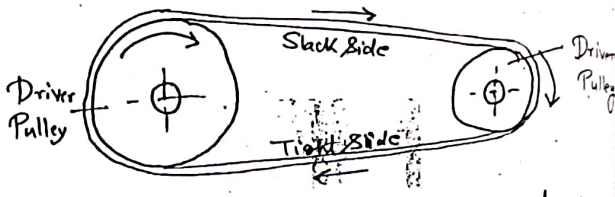


Belt :- A belt is a loop of flexible but resistant body used to link two or more rotating shafts to transmit power from one place to another (only in mechanical form).

Belts may transmit power from a shaft to another shaft, which is parallel or non-parallel to the first one. Belts are looped over a pulley & may have a twist between the pulleys & the shafts need not to be parallel.

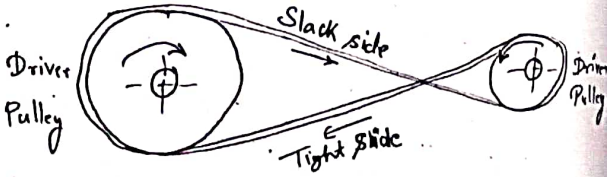
Types of Belt-drives — Belt-drive consists of two pulleys over which a belt is passed.

① **Open-Belt Drive** :-



It provides Rotation in same direction.

② **Cross-Belt Drive** :-



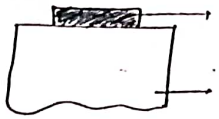
It provides Rotation in opposite direction.

Types of Belts —

The most commonly used belts are as follows —

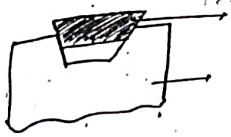
(1) **Flat Belts** —

(Belts having rectangular cross-section)



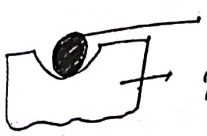
(2) **V-Belts** —

(Belts having trapezoidal cross-section)



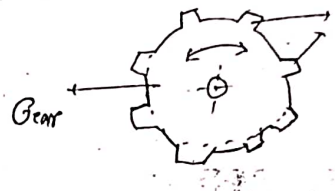
(3) **Round-Belts** —

(Belts having circular cross-section)



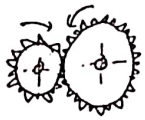
Gears —

A gear is a wheel provided with teeth on its periphery to mesh with the teeth on another wheel, or on a rack; to transmit motion from one component to another.

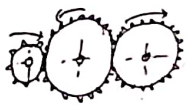


Gear Train —

Two or more gears working together constitute a gear train. A gear train may be defined as "a system of gears arranged to transfer torque (rotational motion) from one component to another is called a gear train."



Gear Train of Two gears

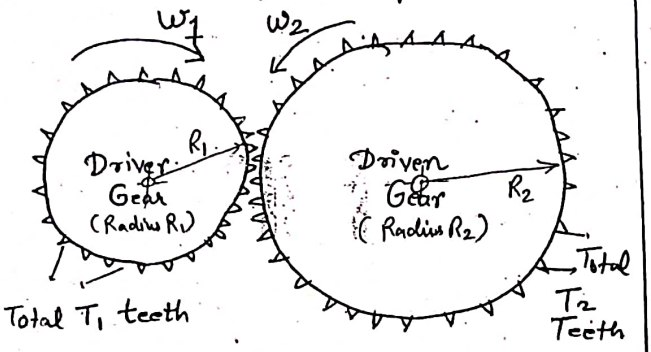


Gear Train of Three gears

Gear Ratio —

Gear Ratio is the ratio of input angular speed to the output angular speed.

$$G.R. = \left[\frac{\omega_{input}}{\omega_{output}}\right]$$



$$\text{Gear Ratio} = \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1} = \frac{\tau_2}{\tau_1} = \frac{R_1}{R_2}$$

Where τ_2 = Output Torque
τ_1 = Input Torque
T_2 = No. of teeth on driven gear
T_1 = No. of teeth on driver gear.

Various Types of Gear —

(1). Spur Gear —
Spur gears transmit power through shafts that are parallel. Their teeth are parallel to the axes of shafts.

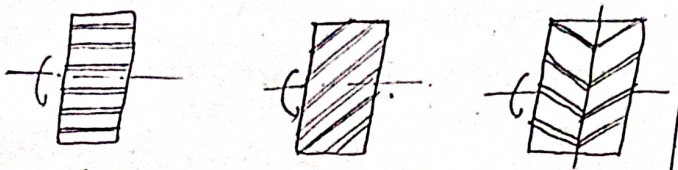
(2). Helical Gear —
Helical gears are having teeth that are oriented at an angle to the shaft.

(3). Herringbone Gear —
Herringbone gears are very similar to the double helical gears, but they do not have a gap as in case of the gap separating the two helical gears

(4). Bevel Gear —
Bevel gears are conical shape gears used to transmit power between shafts intersecting each other at 90°.

(5). Worm Gear —
Worm gears transmit power through shafts intersecting at 90°. A worm & worm wheel are used for this purpose.

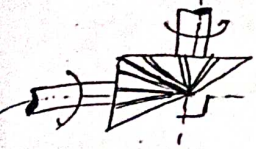
(6). Rack & Pinion —
Rack & Pinion are used to convert Rotary motion into translational motion & vice-versa. A rack (Linear Gear) & Pinion (Circular Gear) are used here.



Spur Gear
(1 Gear)

Helical Gear
(1 Gear)

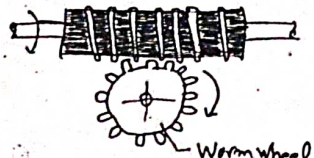
Herringbone Gear
(1 Gear)



Bevel Gear

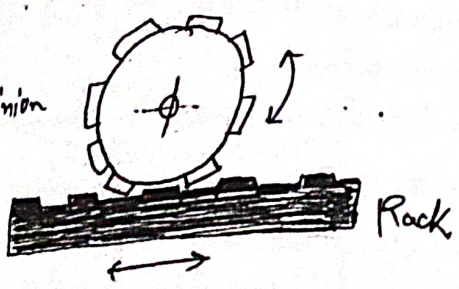
{Two meshing Bevel Gears are shown.}

Worm



Worm Gear

{(Meshing Worm & Worm wheel are shown)}



Rack & Pinion

(Rack & Pinion are shown).

Control valves

One of the most important functions in any fluid power system is control. If control components are not properly selected, the entire system will fail to deliver the required output. Element for the control of energy and other control in fluid power system are generally called 'valves'.

There are 3 basic type of valves

1) Direction control valve
2) Pressure control valve
3) Flow control valves

Direction control valves

- Direction control valves mainly performs three functions:
  - * Stop fluid flow
  - * Allow fluid flow
  - * change direction of fluid flow
- Direction control valves can be classified in a no. of ways
1. According to the types of construction:
   - * poppet valve
   - * Spool valve.
2. According to number of working ports:
   - * Two way valves
   - * Three way valves
   - * four way valves

3. According to Number of switching position.
   * Two position
   * three position.

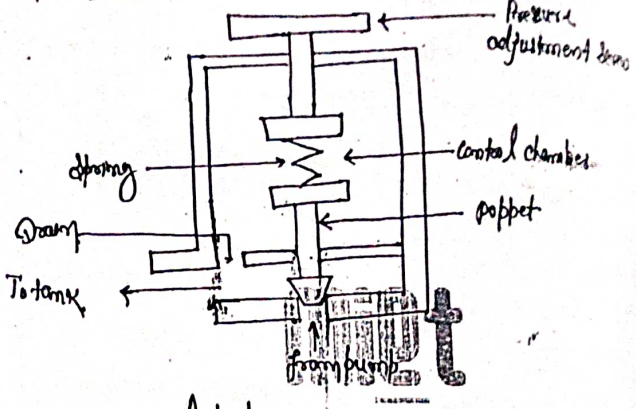
Pressure Control valve

- These units are responsible for control of pressure. A throttling orifice is present in the valve and by variation of orifice, the pressure level can be controlled or at a pressure, a switching action can be influenced.
- The most common valves for controlling pressure include relief, reducing, sequence, counterbalance and unloading valves.

Pressure Relief valve

- The pressure relief valve is an important type of safety valve. A pressure relief valve protects motors, pumps and actuators from becoming damaged from high pressure.
- The valve remains closed for normal operation and no water passes through the valve.
- when the pressure in the loop exceeds the limit the valves opens and release the excess pressure thus protect the expensive machinery.
- Pressure relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow

when the pressure reaches a preset level.
- There are two different designs of relief valves in use.
  * Direct acting
  * pilot operated



Actuators

- The actuator are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion.
- In general hydraulic or pneumatic system are used for gripping and for moving operations in industry. these operations are carried out using actuators.

Actuators are classified into two types
1. Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.

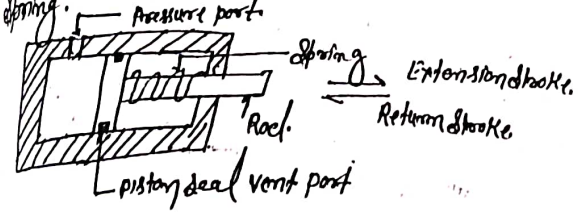
2. Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.

Linear actuators (Cylinders)

- All hydraulic cylinder create linear movement but there are different varieties which have their own unique effects.
- Some of the most common types of hydraulic cylinders are as follows.

Single acting hydraulic cylinder

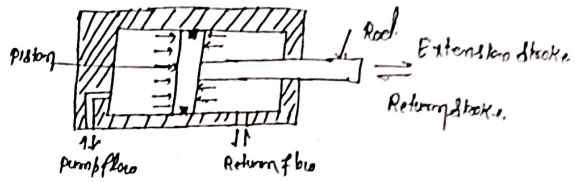
Single acting cylinder operate in one direction only. They have a single port at one end of the cylinder, so when the fluid is pumped into the port it pushes the rod causing it to extend. The rod returns because of an external force such as the load or a spring.



Double acting hydraulic cylinder:

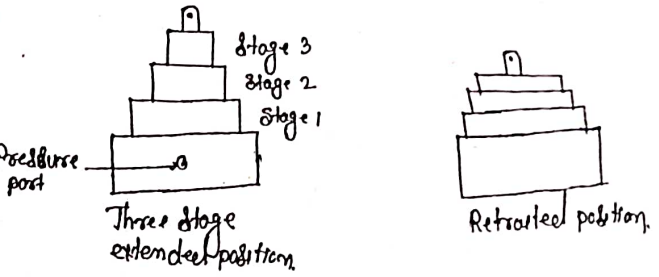
Single acting cylinders which can only push or double acting cylinders do both. They have ports at both ends of the cylinder, so that when oil is pumped into

the head port the piston moves and extends the rod. Oil in the rod end of the cylinder is pushed out into a reservoir. To achieve the opposite movement and retract the rod, the oil flow is reversed



3. Telescopic hydraulic cylinders

→ Telescopic cylinder are as their name suggests, a series of rams inside one another like a telescope. This means they can achieve a comparatively long stroke when all the rams are extended.



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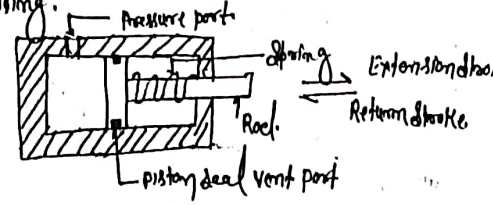
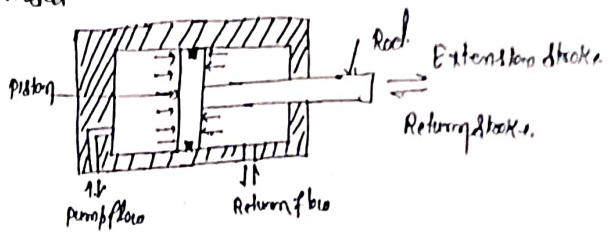


2. Double acting hydraulic cylinder:

- Unlike single acting cylinders which can only push or pull, double acting cylinders do both. They have ports at both ends of the cylinder so that when oil is pumped into

the head port the piston moves and extends the rod. Oil in the rod end of the cylinder is pushed out into a reservoir. To achieve the opposite movement and retract the rod, the oil flow is reversed



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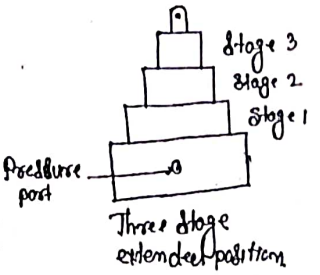
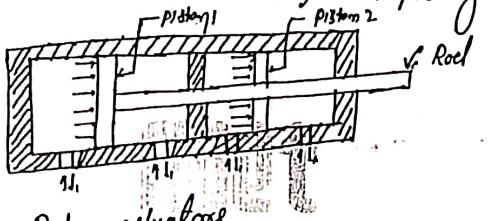


4. Tandem hydraulic cylinder:

- In a tandem hydraulic cylinder, two interconnected cylinders operate together to generate a greater force than one cylinder would be able to create on its own. The two cylinders are supplied by different hydraulic systems, but they are connected mechanically so that the rod of the first cylinder enters the second cylinder, pushing its base



Rotary actuators

- Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but run on hydraulic or pneumatic power

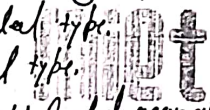
- Gear motors:

- It consists of two interconnecting gears inside a housing with one gear attached to the drive shaft

- The oil enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces.

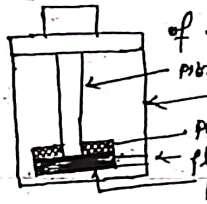
Accumulators

- A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force.
- The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system.
- There are 3 basic types of accumulator used in hydraulic system. They are:
  1) weight loaded or gravity type.
  2) Spring loaded type.
  3) Gas loaded type.



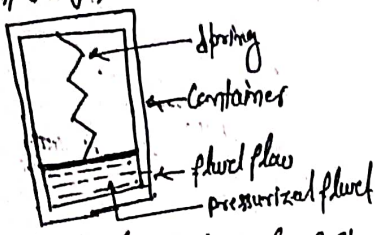
Weight loaded accumulator

- This type consists of a vertical, heavy-wall steel cylinder which incorporates a piston with oil packing to pressurize as shown in the figure.
- A dead weight is attached to the top of the piston. The force of gravity of the dead weight provides the potential energy in the accumulator.



Spring loaded accumulator

- A spring loaded accumulator is similar to the weight loaded type except that the piston is pre loaded with a spring as shown in the fig.

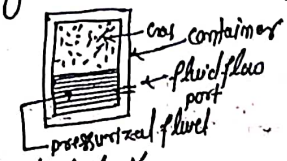


- The spring is the source of energy that acts against the piston forcing the fluid into hydraulic system
- The pressure generated by this type of accumulator depends on the size and pre-loading of the spring.

Gas loaded accumulator

a) Non-Separator type:

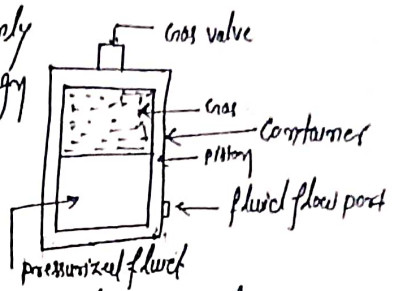
- The non-Separater type of accumulater as shown in fig. consists of a fully enclosed shell containing an oil port on the bottom and a gas charging valve on the top.



- The gas is confined in the top and the oil at the bottom of the shell. There is no physical separator between the gas and oil and thus the gas pushes directly on oil

b) Separator type accumulator:

- The commonly accepted design of gas loaded accumulator is the Separater type. In this type there is a physical barrier between the gas and oil and thus the gas is not in direct contact.



Applications of accumulator

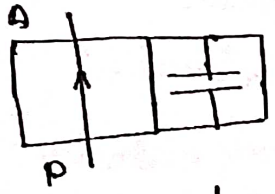
1. Accumulator can be used as auxiliary power source.
2. Accumulator can be used as emergency power source.
3. Accumulator can be used as a hydraulic shock absorber.

Amplifiers

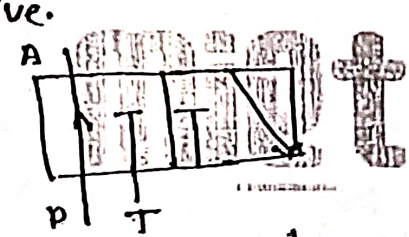
- Amplifier is a part electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output

Pneumatic Sequence

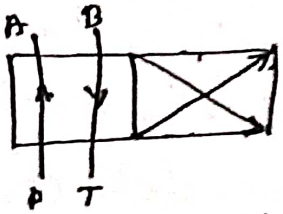
- The no. of ports on a direction control valve (DCV) is usually identified by the terms 'way',
  - A valve with 2 service ports and 2 switching position is designated as 2/2 way valve.
  - A valve with 3 service ports and 2 positions is designated as 2/3 way valve.
  - A valve with 4 service ports and 2 positions is designated as 2/4 way valve.



a) 2/2 way valve.



b) 2/3 way valve.



c) 2/4 way valve.

Q.1 Write the short notes on amplifier.

Ans: Refer to page No 44

Q.2 ① Describe accumulator and its function.

Ans: Refer to page No. 42 to 44.

B. Tech I Year [Subject Name: F. of Mechanical Engineering]

5 Years AKTU University Examination Questions		Unit-5	
S No	Questions	Session	Lecture No
1	What do you mean by measurement? What are the different methods of measurement?		
2	Explain the term error in measurement. What are different types of Error?		
3	Explain the difference between systematic and random errors. What are the typical sources of these two types of error?		
4	What is calibration and its need? What is the basic principle of calibration?		
5	With a block diagram, explain the three stages of a generalized measurement system giving suitable examples.		
6	Explain various errors in measurements and the practice which are needed to be minimize them.	2020-21	
7	State the four different pressure measurement scales.		
8	With a neat diagram, explain the relationship between absolute, gauge, and barometric pressures.		
9	Discuss the working of a Bourdon gauge with a neat sketch.		
10	Write a note on vacuum and high pressure measurement.		
11	Compare the different temperature scales.		
12	Explain the different methods for temperature measurement. Discuss the construction and working of thermocouple?		
13	Discuss the types of flow meters and explain any one in detail?		
14	A simple U-tube manometer containing mercury is connected to a pipe in which a fluid of sp. gravity 0.8 and having vaccum pressure is flowing. The another end of manometer is open to atmosphere. Find the vaccum pressure in pipe, if the difference of mercury level in the two limbs is 40cm and the height of the fluid in the left tube from the centre of pipe is 15cm below.		
15	What is a strain gauge? Explain the different methods to calculate strain?		
16	What are the different methods to calculate force?		
17	What are the different methods to calculate torque?		
18	Differentiate between accuracy and precision?	2020-21	
19	Write the short notes on measurement resolution and accuracy.		
20	Define Mechatronics. Write the advantages, disadvantages and application of Mechatronics.		
21	Define mechatronics along with the key elements of a mechatronic system?		
22	Compare the traditional and mechatronic approach.		
23	How mechatronics evolved over the period of time?		
24	Discuss the scope of mechatronics for engineers.		

25	What are Autotronics, bionics and avionics? Write their applications. Explain any four autotronics systems.		
26	Write the short notes on bionics implants.		
27	What are sensors and transducers? Enumerate the various types of sensors and transducers.		
28	Write the name of sensor or transducer used for measuring displacement, velocity, and pressure and temperature.		
29	Discuss on the static and dynamic characteristics transducers		
30	Define Kinematic chain with the help of diagram. Define the four bar chain and its inversions.		
31	What is the CAM? Define its function and application. What are the types of CAM and followers?		
32	Describe the different types of gears with diagram. Define gear ratio and gear train.		
33	Explain the mechanism of Ratchet -pawl and its applications.		
34	What is the belt drive? What are the different types of flat belts drives.		
35	Write the definition of bearing and its classification.		
36	What is pressure control valve? Also explain its working.		
37	How does direction control valve work?		
38	Describe accumulator and its function?		
39	Explain the working of rotary actuator.		
40	Write the short notes on Amplifiers.		