KME-101T

UNIT-5

Fundamental of Mechanical Engineering and Mechatronics

Syllabus

Introduction to Mechatronics :- Evolution, scope, Advantages and disadvantages of Mechatronics, Industrial applications of Mechatronics introduction to autotronics, bionics and avionics and their applications.

Sensors and Transducers :- Types of sensors, types of transducers and their characteristics.

overview of Mechanical Actuation system :- Kinematic chains, cam, Train Ratchet mechanism, Gears and its type, Belt, Bearing

Hydraulic and Pneumatic Actuation systems :- overview : Pressure control valves, cylinders, Direction control valves, Rotary Actuators, Accumulators, Amplifiers and Pneumatic Sequencing Problems.

The word Mechatronics was first coined by Mr. Tetsuro Moria, a senior engineer of a Japanese company, Yaskawa in 1969.

Mechatronics may alternatively be referred to as "electromechanical systems" or as "smart products".

<u>Definition</u>- Mechatronics is the "Synergistic Integration of Mechanical Engineering with electronics and Intelligent Control algorithm in the design and Manufacture of products process".

<u>Examples</u>- Industrial Robots, Fuel injection systems

<u>Evolution</u> evolution of Mechatronics consist of four levels.

1. Primary Level
2. Secondary Level
3. Tertiary Level
4. Quaternary Level

- <u>Primary Level</u>- Integrates electrical signaling with mechanical action at the basic control level.
  <u>Ex</u>:- Fluid valves and relay switches.

- <u>Secondary Level</u> - Integrates microelectronics into electrically Controlled devices.
  <u>Ex</u>:- cassette tape Player.

- <u>Tertiary Level</u>- Incorporates advanced control strategy using microelectronics, microprocessors and other application specific integrated circuits.
  <u>Ex</u>:- Microprocessor based electrical motor used for Actuation purpose in robots.

Quaternary Level - This level attempts to improve smartness a step ahead by introducing intelligence (artificial neural network and Fuzzy logic) and Fault detection and isolation (F.D.I.) capability into the system.

Scope

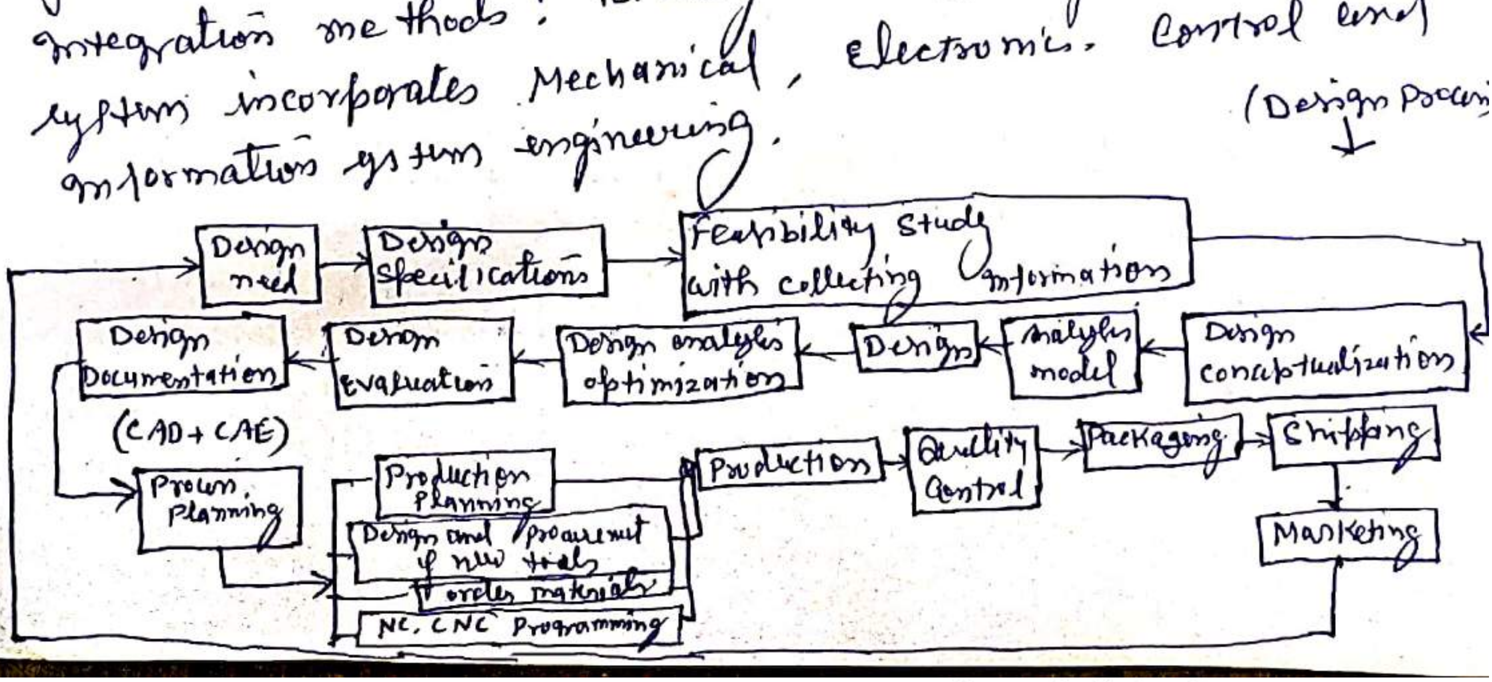
The field of Mechatronics is very promising when it comes to job opportunities. Some areas where the knowledge of Mechatronics is applied are - Robotics, Telecom Sector, Mechanical Systems, electrical systems, Biomedical system, Automation, Nanotechnology, Metallurgy and Bio mechatronics.

Mechatronics in Marketing :- signifies market research, identification of user needs, information analyses and formulation of Product specification.

Mechatronics in Manufacturing :- Looks into process Development, Production planning, material handling and Quality Control.

Design in Mechatronics :- The concentration is on studying fundamental aspects of sensors, actuators, control and integration methods. Broadly the core of a mechatronics system incorporates Mechanical, Electronics, Control and information system engineering.

(Design Process)



Advantages and Disadvantages of Mechatronics

Advantages

- Cost effective and reliable product
- Adaptation possibilities
- Simplified mechanical design
- Rapid M/C setup
- Rapid development trials
- Optimized performance, productivity reliability

Disadvantages

- High initial cost of the system
- Different expertise required
- More complex safety issues
- Increase in component failures
- Lifetime changes / vary
- Increased power requirements
- real-time calculations / mathematical modes.

Industrial Applications of Mechatronics

Machine vision
Automation and robotics
Servo-mechanics
Sensing and Control systems
Automotive engineering (Anti-lock braking)
Building Automation / Home Automation
Computer M/C Controls (CNC milling, CNC waterjet)
expert systems
Industrial Goods
Consumer products
Mechatronics systems
Medical Mechatronics
structural dynamic system
Packaging
Micro controllers / PLCs
Microprocessors.

Autotronics Autotronics is referred to as modern automotive technology in the field of automobile engineering. It could be describe as an artificial word that combines automotive field and electronics content and it owns many applications in motor vehicles technology.

- Direct Fuel Injection
- electric AC compressor
- Continuously variable Transmission
- Active suspension
- electric Brake
- electric Assist Power Steering
- 42 volt Converter
- crankshaft starter generator
- electric water pump
- Electric valve Control

Bionics Bionics or Biologically inspired engineering is the application of biological method and systems found in nature to the study and design of engineering systems and modern technology.

- In computer science, cybernetics tries to model the feedback and control mechanisms that are inherent in intelligent behavior, while artificial intelligence tries to model the intelligent function.
- In robots bionics are used to apply the way animals move to the design of robots. Bionic Kangaroo was based on the movements and physiology of Kangaroos.
- In medicine Bionics means the replacement or enhancement of organs or other body parts by mechanical versions

Avionics :- Avionics are the electronic systems used on aircraft, artificial satellites and spacecraft.

Avionic systems include communications, navigation the display and management of multiple systems. and the hundreds of systems that are fitted to aircraft to perform individual functions.

These systems may be as simple as a searchlight for a police helicopter or as complicated as the tactical system for an airborne early warning platform.

" The term 'Avionics' was coined in 1949 by "Philip J. Klass". Senior editor at 'Aviation week & space Technology magazine".

- Radio communication was first used in aircraft just prior to world war 1.

- Radar as an air defense system was developed in 1930s during the runup to world war II..

Modern Avionics :- Avionics plays a heavy role in modernization initiatives like the Federal Aviation Administration Next generation Air Transportation systems in the United states.

Avionics in 6 Areas -

- Published routes and procedures - improved navigation and routing
- Negotiated Trajectories - Adding data communications to create preferred routs dynamically.
- Delegated separation - enhanced situational Awareness in the air and on the ground.

- Low visibility / ceiling Approach / Departure - Allowing operations with weather constraints with less ground infrastructure
- Surface operations - To increase safety in approach and departure.
- ATM efficiencies - Improving the ATM process.

Aircraft Avionics

- communications
- Navigation
- Monitoring
- Aircraft Flight Control System
- Fuel Systems
- collision - avoidance system
- Flight recorders
- weather systems
- Aircraft Management system.

Sensors and Transducers

- Types of Sensors
- Types of Transducers
- characteristics of sensors and Transducers.

Sensor :- A sensor is defined as a device which measure a physical quantity (light, sound, space) and converts them into an easily readable format. If calibrated correctly, sensors are highly accurate devices.

- "Not all transducers are sensors, but most sensors are transducers".

Ex :- A Thermistor is a type of sensor ; it will respond to the change in temperature but does not convert the energy into a different format to what it was originally sensed in.

(Thermistor) (Symbol)

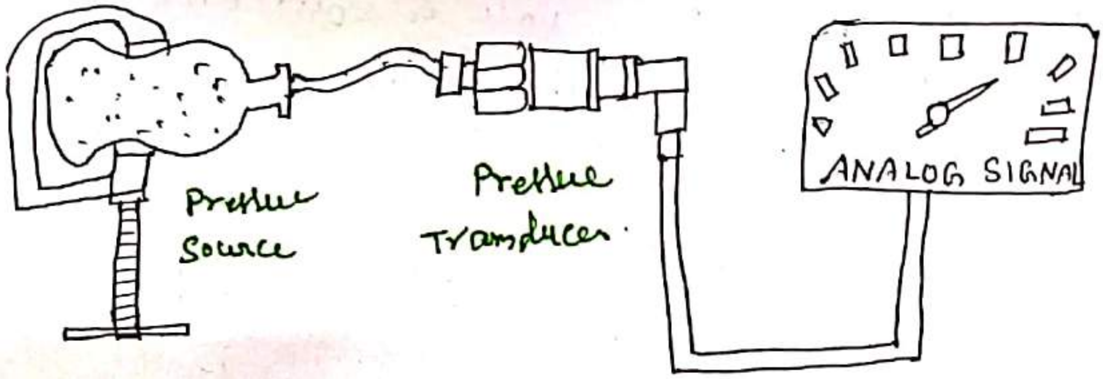
Transducer :- Transducer is an electronic device which converts energy from one form to another.
There are 6 types types of measurements can be performed by transducer.

- Mechanical Measurement
- Magnetic Measurement
- Thermal Measurement
- Electric Measurement
- Chemical Measurement
- Radiation Measurement

"A transducer can take a measurement in one format and convert it to another".

"A Thermistor on its own a sensor but, when it is incorporated into a bigger circuit or device it will become an element of a transducer.

Ex:- Thermometer is a transducer

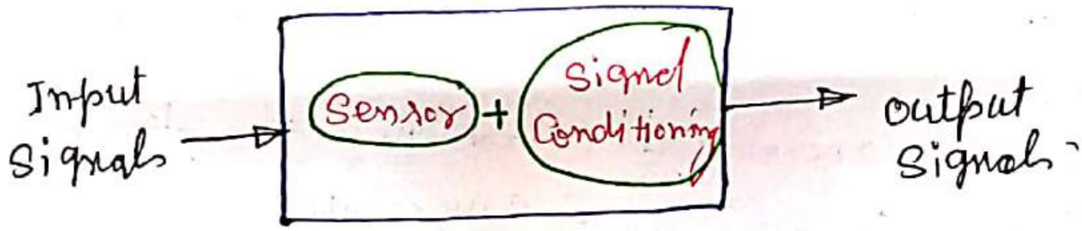


A pressure Transducer (sometimes called a Pressure transmitter) converts Pressure into an analog electrical Signal.

The main difference between a Sensor and a Transducer is that a sensor senses the difference or change in the environment they are exposed to and gives an output in the same format whereas a transducer takes a measurement in one form and converts it to another.

For example, a measurement which is not electrical and converts it into an electrical signal. This process is called "transduction".

Transducer:



	Sensor	Transducer
Working Principle	• Senses a physical measurement and makes it readable for the user but keeps it in the same format	• Senses the physical measurement and converts it from one form to another. eg. - Non-electrical to electrical.
Examples:	• Thermistor, motion sensor, Pressure switch	• Microphones, Pressure transducer, linear transducer.
Uses/Applications	• Patient monitoring, infrared toilet flushes, liquid dispensing in drinks MIC's.	• HVAC monitoring engine controls steering system ramp and bridge lifting system

Classification of Sensors and Transducers

Sensors are generally classified into the following two types based on its power requirement.

- Active Sensor
- Passive Sensor

Active Sensor - In active sensors, the power required to produce the o/p is provided by the sensed physical phenomenon itself. Active sensors are also called self-generating transducers.

Ex:- Thermocouples, Photovoltaic cells, Piezoelectric transducer thermometer etc.

Passive Sensor - Passive sensors require external power source.

Ex:- Resistance thermometers, potentiometric devices, differential transformers, strain gauge etc.

Passive sensor work based on one of the following principles

- Resistance
- Inductance
- Capacitance

Classification of sensors based on the type of o/p signal.

- Analog Sensor
- Digital Sensor

Analog Sensor - Analog sensors produce continuous signals that are proportional to the sensed parameters. These sensors generally require analog to digital conversion before

Sending o/p signal to the digital controller.

Ex.- Potentiometers, LVDT, Load cells and thermistors. bourdon tube pressure sensor, spring type force sensor, bellow pressure gauge etc.

Digital Sensor - Digital sensor on the other hand produce digital o/p's that can be directly interfaced with the digital controller.

Ex.- Incremental encoders, photovoltaic cells, piezoelectric transducers, phototransistors, photo diodes etc.

Classification of sensor based on type of o/p

- Primary Sensor
- Secondary Sensor

Primary Sensor - It produce o/p which is direct measure of the input phenomenon.

Secondary Sensor - It produce o/p which is not the direct representation of the physical phenomenon.

Active Sensor - Primary Sensor

Passive Sensor - Secondary Sensor

Classification of sensor based on the principle of operation

- Resistive
- Capacitive
- Inductive
- Ultrasonic
- Piezoelectric
- Piezoresistive
- Photoelectric

Types of sensors based on various measurement objectives.

(Quantity to be measured)	(Type of Sensor)
Linear / Rotational displacement	LVDT / RVDT optical encoder electrical tachometer Hall effect Sensor capacitive transducer Strain Gauge Elements Interferometer Magnetic pick up Gyroscope
Proximity	Inductance Sensor Eddy current Sensor Hall effect Sensor Photoelectric Sensor Capacitance Sensor
Force, torque and pressure	Strain Gauge Dynamometers / Load cells Piezoelectric Load cells Tactile sensor Ultrasonic stress Sensor

Quantity to be measured	Type of Sensors
velocity and Acceleration	Electromagnetic Sensor Ultrasonic sensor Tachogenerators Resistive sensor Capacitance Sensor Piezoelectric sensor Photoelectric Sensor Electron tube
Flow	Pitot tube orifice plate Flow Nozzle venturi tubes Rotameter Ultrasonic Flow meter Turbine Flow meter Electromagnetic Flow meter
Level	Float Level Sensor Pressure Level Sensor Resistive Sensor variable capacitance Sensor Piezoelectric Sensor Photoelectric Sensor

Quantity to be measured	Type of Sensor
Temperature	Thermo couples Thermistors Thermodiodes thermo transistors Resistance temperature detector (RTD) Infrared thermography
Light	Photo resistors Photo diodes Photo transistors Photo conductors charge coupled diode

Classification of Transducers :-

1. Electrical (Resistive, capacitive, inductive, thermo electric, resonant etc.)
2. Solid State (Magnetic, thermal, mechanical, chemical etc.)
3. Optical (Radian energy, Photo detector, vision system, Laser Scanning, fiber optic etc.)
4. Piezo-electric (Accelerometer, humidity meter, light modulator, Actuators, Acoustic devices etc.)
5. Ultrasonic (Flow measurement, distance, velocity, ultrasonic imaging etc.)

Static and Dynamic characteristics of Sensor and Transducer :-

Static characteristics relate to the performance of a transducer when the measured quantity is essential constant, the dynamic characteristics relate to dynamic inputs, which means that they are dependent on its own parameters as well as the nature of the input signal.

Static characteristics -

- Static Error
- Accuracy
- Precision
- Sensitivity
- Reproducibility
- Hysterisis
- Drift
- Dead zone

Static characteristics

Desirable

- Static Error
- Accuracy
- Precision
- Sensitivity
- Reproducibility
- Resolution

Undesirable

- Hysteresis
- Drift
- Dead zone
- Dynamic error

Static Error - The difference between the true value of the measuring quantity to the value shown by the measuring instrument under not varying process conditions.

[Static Error = True value of a measured/variable − Instrument reading]

+ve static error means instrument reads high

-ve static error means instrument reads low

Accuracy - Accuracy may be defined as the degree of closeness with which the instrument reading approaching the true value of the quantity to be measured.

- Measured quantity may be different from the true value due to the effects of temperature, humidity etc.
- Accuracy is expressed in the "percentage of full scale reading".
- The best way to develop the ideas of accuracy is to specify it in terms of the percentage of the true value of a quantity being measured.

Precision - Precision is the degree of exactness for which the instrument is designed.

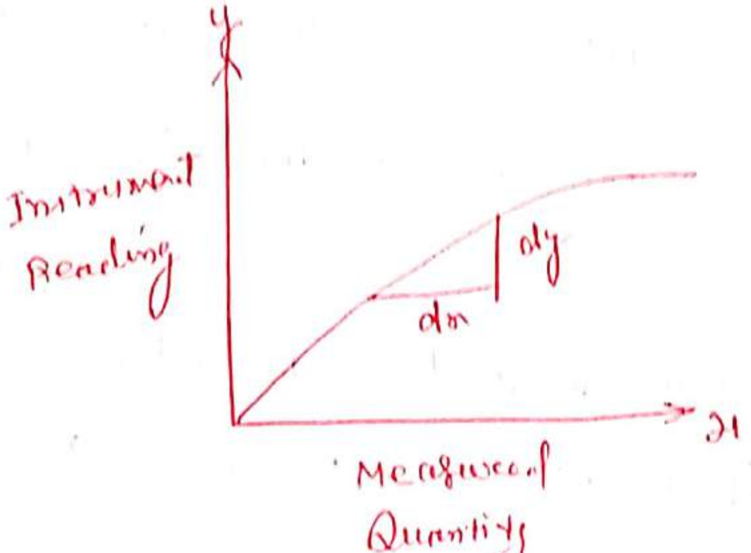
- It composed of two characteristics
  - → conformity
  - → significant figures
- More significant figures, estimated precision is more.

Sensitivity - sensitivity can also be derived as for the smallest changes in the measured variable for which the instrument responds.

Scanned with CamScanner

• Sensitivity can be defined as the ratio of a change in o/p to change in I/p, which causes it in steady-state conditions.

• The usage of this term is generally limited to linear devices, where the plot of o/p to I/p magnitude is straight.



(Sensitivity of Measurement)

$$\left[\text{Sensitivity} = \frac{\text{change in o/p}}{\text{change in I/p}} \right]$$

• Sensitivity of the instrument should be high

<u>Reproducibility</u> - Under the different measurement conditions if the successive measurements of the same variable produce agreed results are called Reproducibility.

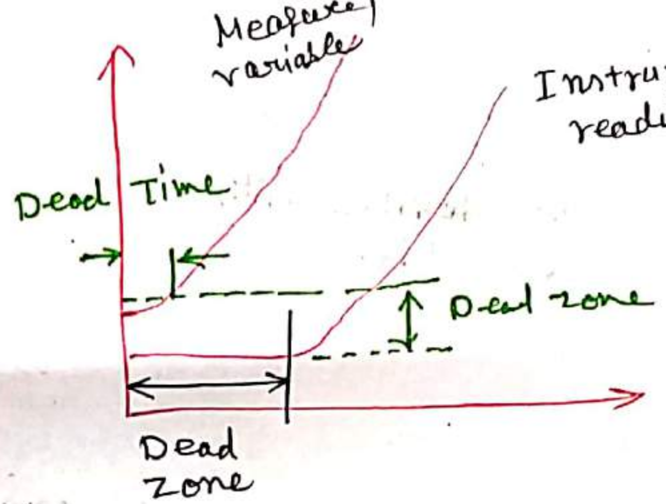
<u>Resolution</u> - It is the smallest quantity being measured which can be detected with certainty by an instrument.

• If a non-zero input quantity is slowly increased the o/p reading won't increase until some minimum change in the I/p takes place.

Dead Zone - for the largest range of values of a measured variable, to which the instrument does not respond.

- Dead zone occurs more often due to static friction in indicating an instrument.

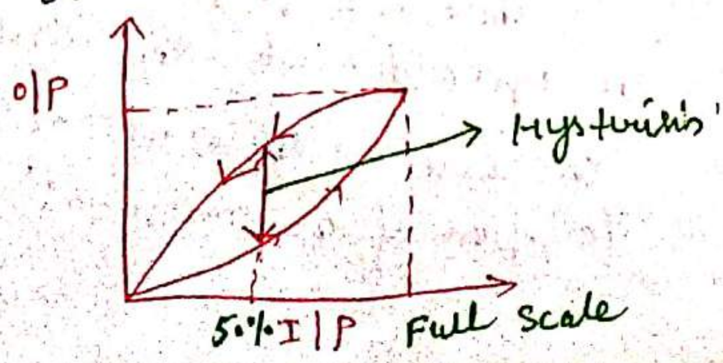
Practical ex. - Due to static friction, a Control valve does not open even for a large opening signal from the Control.



Hysteresis - Hysteresis is a phenomenon that illustrates the different O/P effects when loading and unloading.

- Many times, for the increasing values of input an instrument, may indicate one set of o/p values. For the decreasing values of the input, the same instrument may indicate its different set of o/p values.

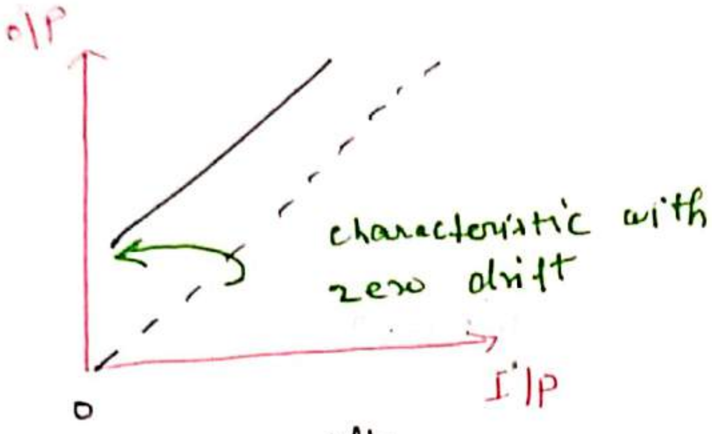
- When o/p values are plotted against input the following kind of graph is obtained.



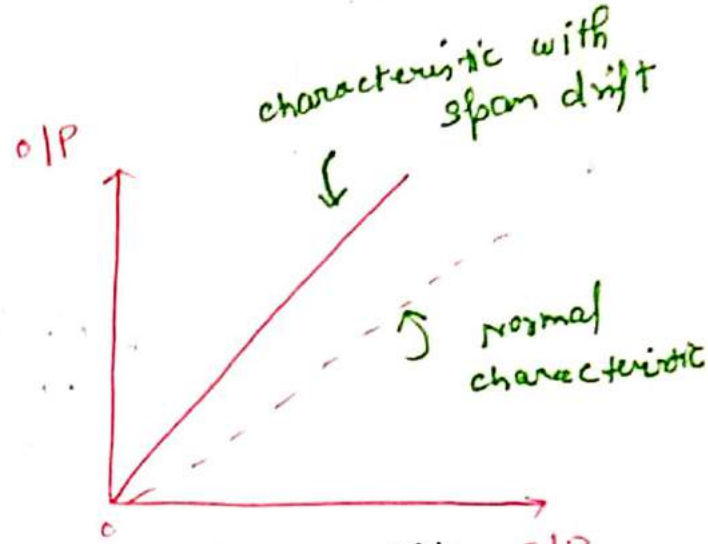
Drift - Drift is an undesired change in the o/p of a measured variable over a period that is unrelated to the changes in o/p, operating conditions, load.

Drift is further classified as:

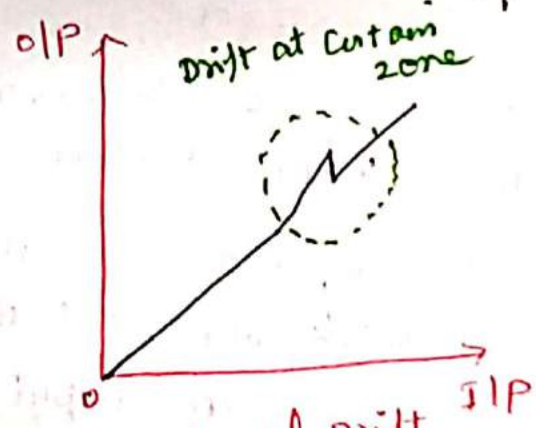
- zero Drift
- span Drift
- zonal Drift



Zero Drift



Span Drift



Zonal Drift

Zero Drift - The zero drift is defined as the deviation in the measured variable starts right from zero in the o/P with time.

Span Drift - If there is a proportionate change in its indication right along the upward scale the drift is termed span drift.

zonal drift - In case if the drift occurs only a certain portion of the span of an instrument, It is called zonal drift.

Dynamic characteristics -

- Dynamic error
- Speed of Response
- Fidelity
- Lag.

Dynamic characteristics

- Desirable
  - Speed of Response
  - Fidelity
- Undesirable
  - Dynamic error
  - Lag

Dynamic error - The difference b/w the true value of the measured quantity to the value shown by the measuring instrument under varying conditions.

Speed of Response - It is defined as the rapidity of the measurement system that responds to the changes in the measuring variable.

- It indicates how active and fast the system is

Fidelity - It is defined as the degree to which a measuring instrument is capable of faithfully reproducing the changes in I/P, without any dynamic error.

Lag - Every system takes at least some time to respond whatever time it may be to the changes in the measured variable.

Ex.- Lag occurs in temperature measurement by temperature sensors such as Thermocouple or RTD or dial thermometer due to scale formation on thermowell due to porous liquid.

Retardation lag - The response of the measurement begins immediately after the change in measured quantity has occurred.

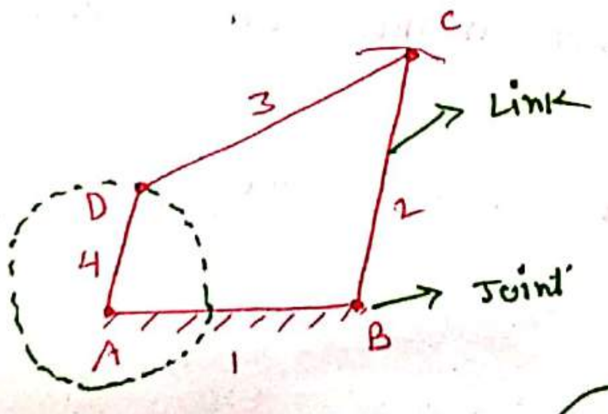
Time delay lag - In this case after the application of I/P, the response of the measurement system begins with some dead times.

Overview of Mechanical Actuation System

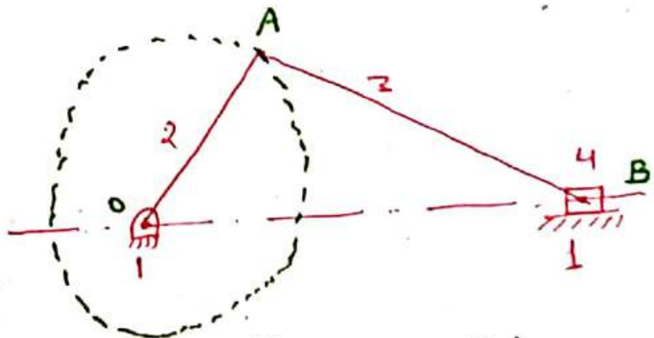
Kinematic chain - In mechanical engineering, a kinematic chain is an assembly of rigid bodies connected by joints to provide constrained (or desired) motion that is the mathematical model for a mechanical system. As in the familiar use of the word chain, the rigid bodies, or links are connected by their connections to other links.

Types of Kinematic chains -

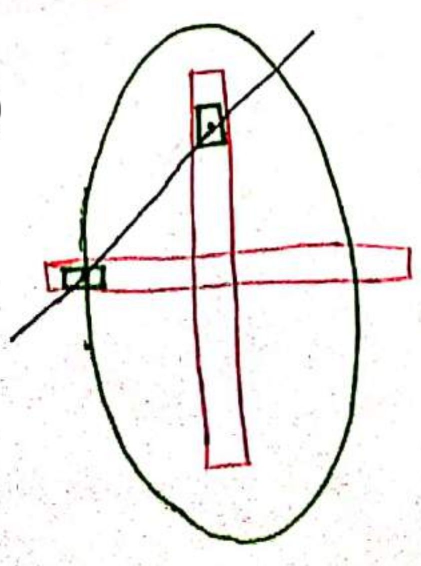
- Four bar chain or Quadric cyclic chain
- Single slider crank chain
- Double slider crank chain



(Four bar chain)



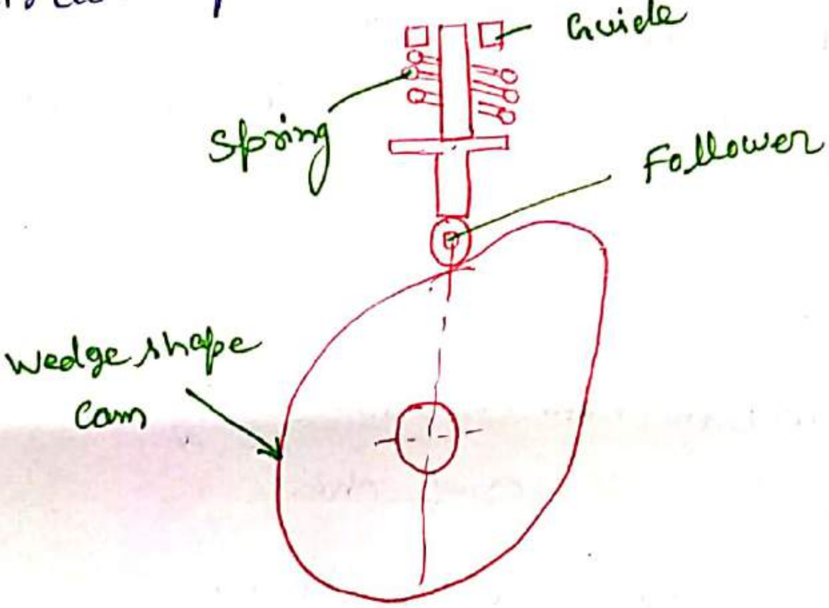
(Single slider Kinematic chain)



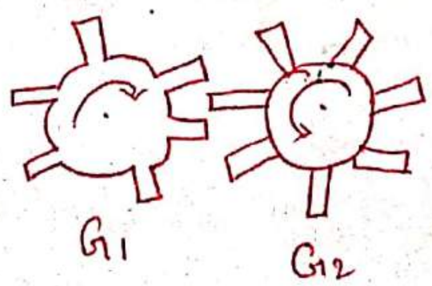
(Double slider Kinematic chain)

[Elliptical Trammel]

Cam - A cam is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion.
It is often a part of a rotating wheel (Ex - an eccentric wheel) or shaft that strikes a lever at one or more points on its circular path.



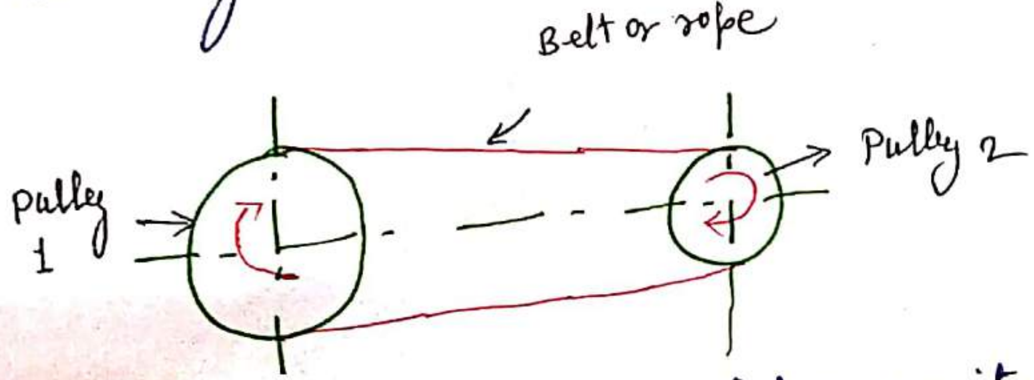
Gears - A gear is a rotating circular M/c part having cut teeth or in the case of a cog wheel or gear wheel, inserted teeth, which mesh with another toothed part to transmit torque.
Geared devices can change the speed, torque and direction of a power source.



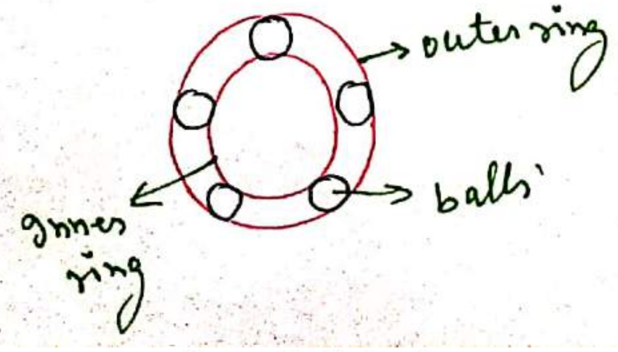
Types of Gears -

- Spur Gear
- Helical Gear
- Double Helical Gear
- Herringbone Gear
- Bevel Gear
- Worm Gear
- Hypoid Gear

Belt - A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. As a source of motion, a conveyour belt is one application where the belt is adapted to carry a load continuously b/w two points.



Bearing - A bearing is a M/C element that constraints relative motion to only the desired motion, and reduces friction between moving parts.



Hydraulic and Pneumatic Actuation Systems -

overview, Pressure Control valves, cylinder, Direction Control valves, Rotary Actuators, Accumulators, Amplifiers and Pneumatic Sequencing Problems.

Pressure Control valves - Pressure Control valves are found in virtually every hydraulic system, and they assist in a variety of functions. from keeping system pressure safely below a desired upper limit to maintaining a set pressure in part of a circuit.

Types of Pressure Control valves -

- Pressure Relief valve
- Pressure reducing valve
- Pressure sequence valve
- Pressure Counterbalance
- Pressure Unloading