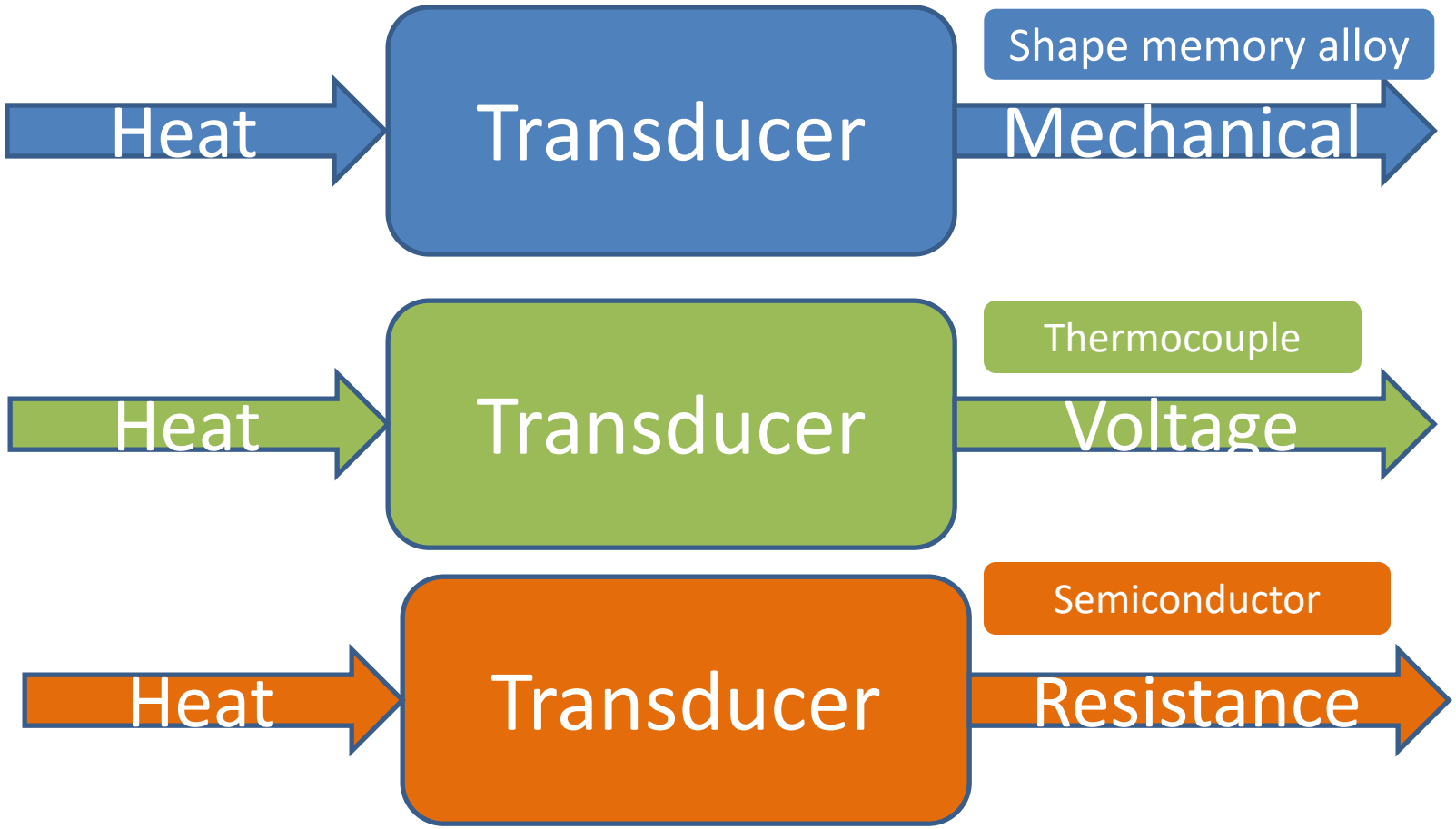
AE 242
Aerospace Measurements Laboratory

Instrumentation

Transducers

Converts one form of energy to another

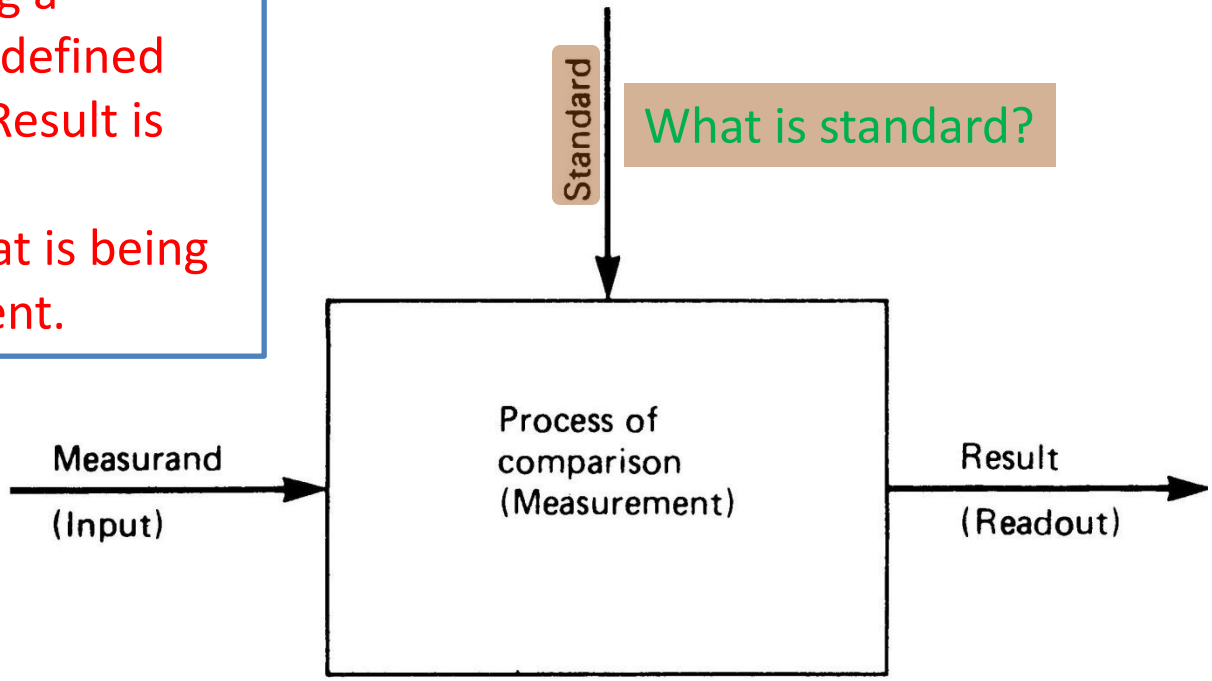


What is measurement?

The act of or process of measuring (English dictionary)

We are concerned about measuring engineering quantities: Temperature, Pressure, Flow, Speed, Acceleration, Angular rate, Linear displacement, Angular displacement etc.

Measurement is : Obtaining a comparison between a predefined standard and measurand. Result is the measured quantity.
Measurand - A quantity that is being determined by measurement.



What is Instrumentation?

Measurement system : Creating instruments for measurements

Measurement instruments interact with the physical quantity and develop output signal

Simple example : Measuring tape for distance measurement, vernier scale, dial gage etc.
Complex example : GPS for position

Absolute measurement – Temperature, pressure
Relative measurement – Differential temperature and pressure

Instrumentation needs information about the interaction with physical quantity e.g. temp & voltage, distance & resistance etc. Modern instruments use electronic devices, micro-controllers etc

Why Instrumentation?

1) Monitoring of processes and operation
2) Control of processes and operation
3) Experimental engineering analysis

1) <u>Monitoring of processes and operation</u>
Barometer, thermometer, anemometer etc in a weather bureau.
Electric meter, water meter at home.
Simply indicates the values

Monitoring

Control

Engineering Analysis

Why Instrumentation?

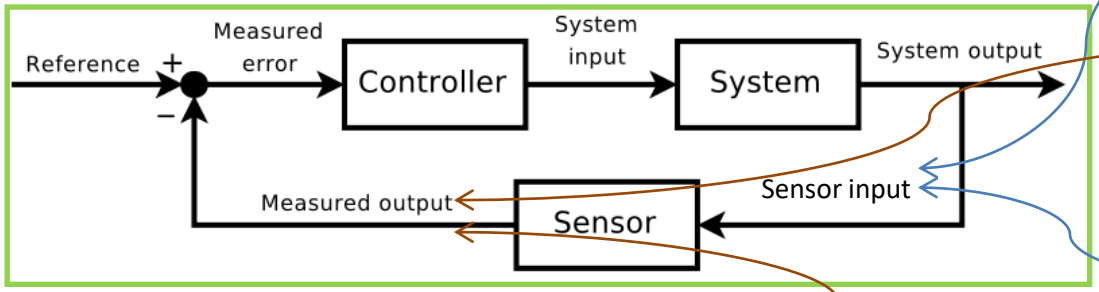
2) Control of processes and operation

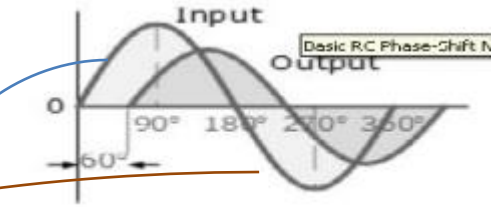
Measured quantity is used to control a process. Measured quantity is used as feed back.

Control of speed in a vehicle: Vehicle speed from odometer, human uses this measurement for control. Human in feed back loop.

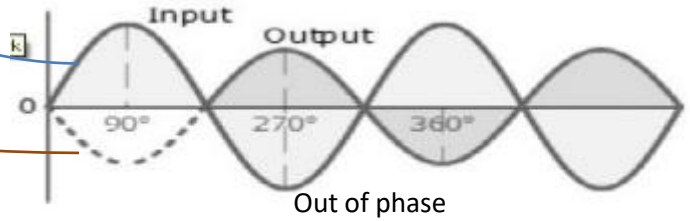
Automatic control : Control system uses the vehicle speed measurement in the feed back system

Quality of the instrumentation (accuracy and reliability) is very important in controls.





In phase



Out of phase

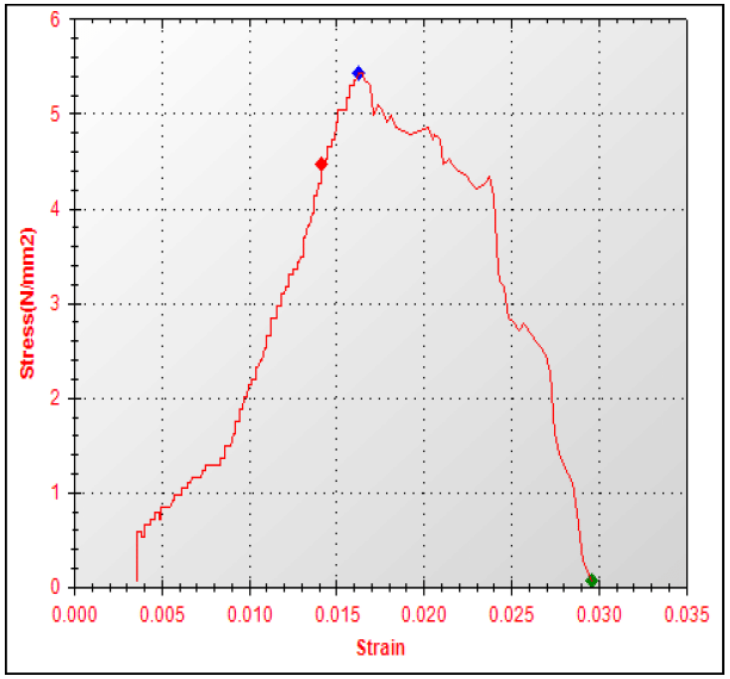
Why Instrumentation?

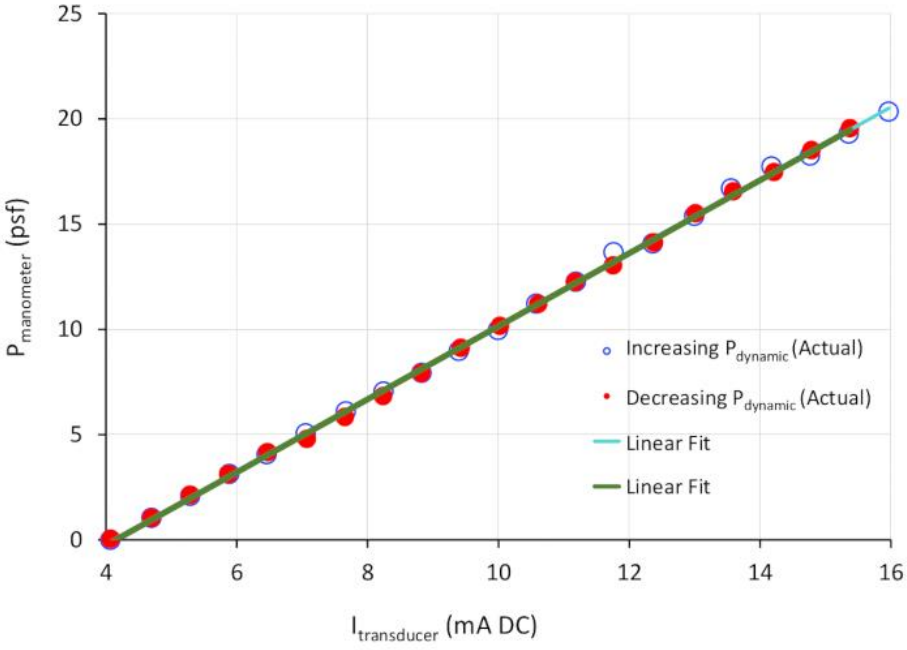
3) Experimental engineering analysis

Measured quantity/quantities are compared with theoretical results.

Theory and experiments compliments each other.

Many times theories are not available, experiments are conducted to get the insight





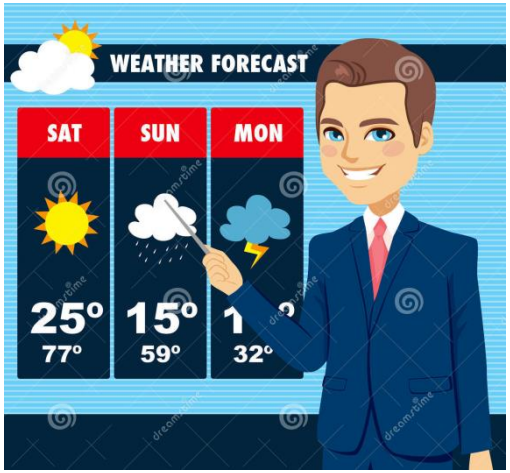
Why Instrumentation?

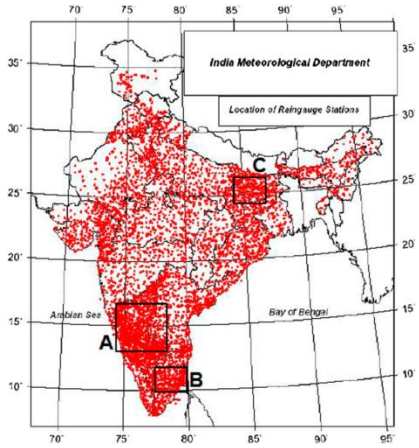
Measured quantity have different meaning for different applications.

Temperature, Barometer, anemometer etc. weather bureau

- For general public it is just a monitoring data
- For a fruit grower, water requirement, anti frost deployment etc
- For a weather analyst, data from large area may be used for prediction

Quality and quantity of measured quantity depends on the end use





Body temperature measurement

Pressure measurement

What are the common functions in above measurement systems?

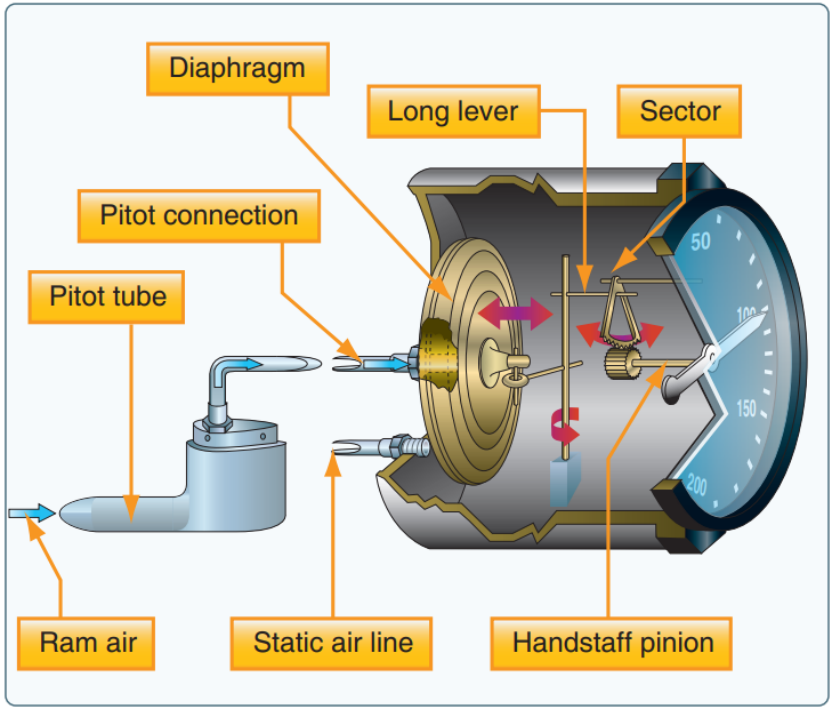
Functional elements of a measurement system

$$V = \sqrt{2\Delta p / \rho}$$

Differential pressure → Air Speed

Human needs information which can be comprehended

Functional elements of a measurement system



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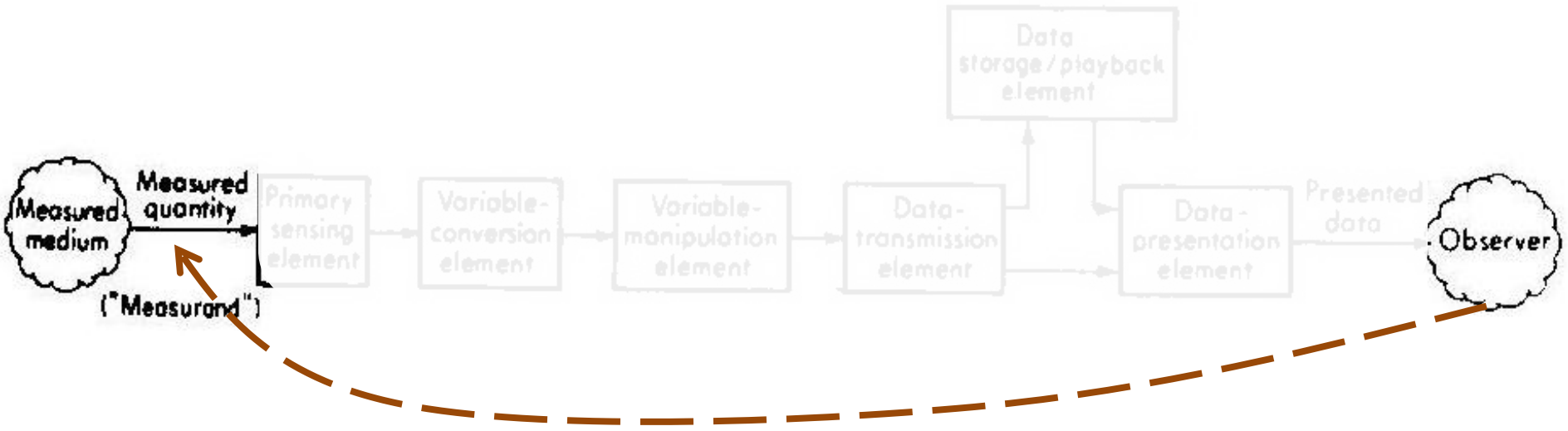
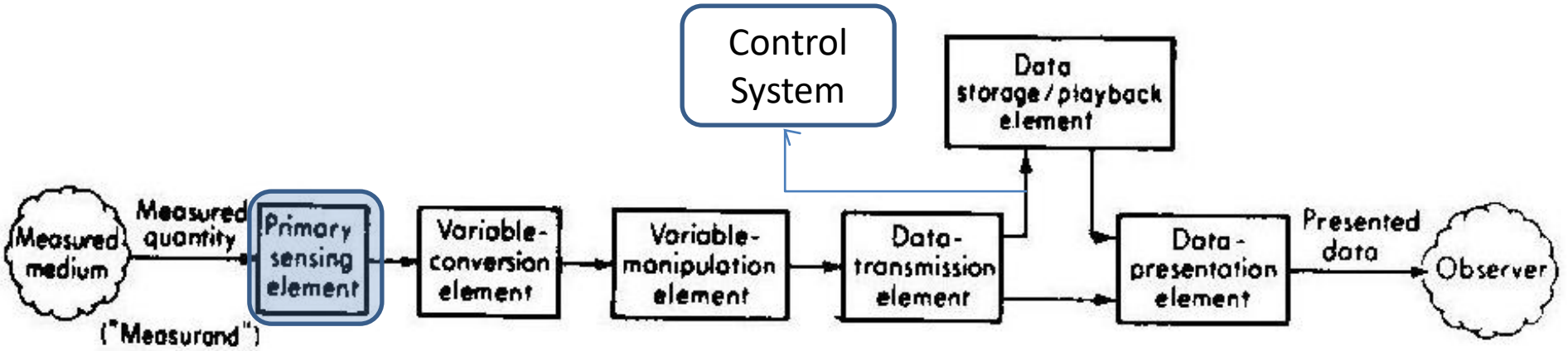
Functional elements of a measurement system



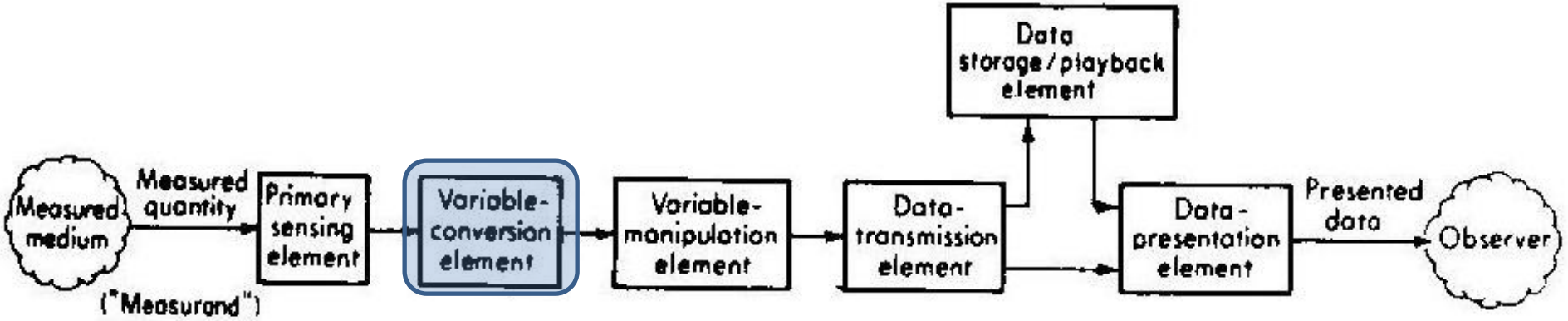
Observer has interest in measured quantity. It may not be directly available, may have intermediate steps.

Functional elements of a measurement system



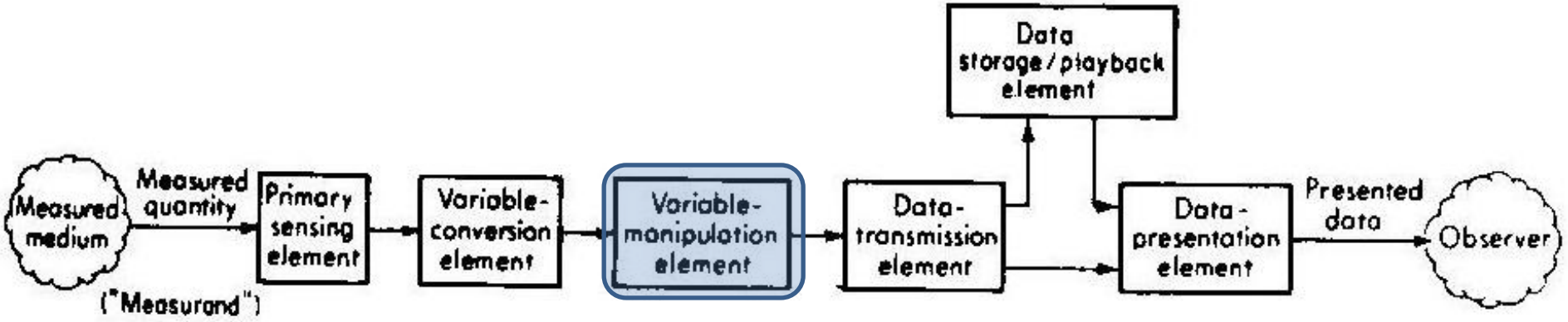
Primary sensing element: It converts measured quantity (measurand) into some other form. Output of primary sensing element converts into some other convenient variable while preserving the information content of the original signal. Electrical quantity (resistance, capacitance, inductance, voltage and current) is preferred. Easier to process. E.g. Resistance is proportional to temperature.

Functional elements of a measurement system



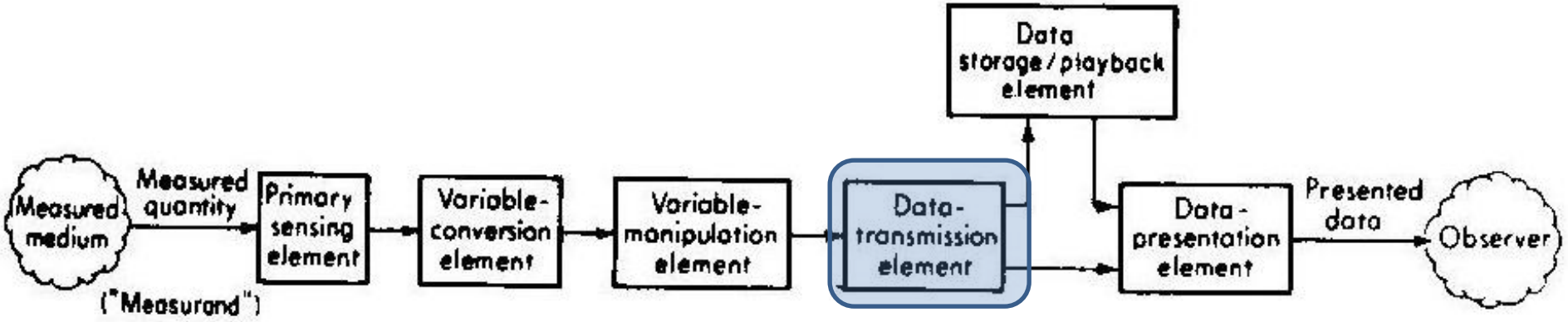
Variable conversion element: This element will convert output of the primary sensing element to another variable suitable for instrumentation. e.g. strain measurement: strain to resistance (strain gage) and resistance to voltage (Wheatstone bridge).

Functional elements of a measurement system



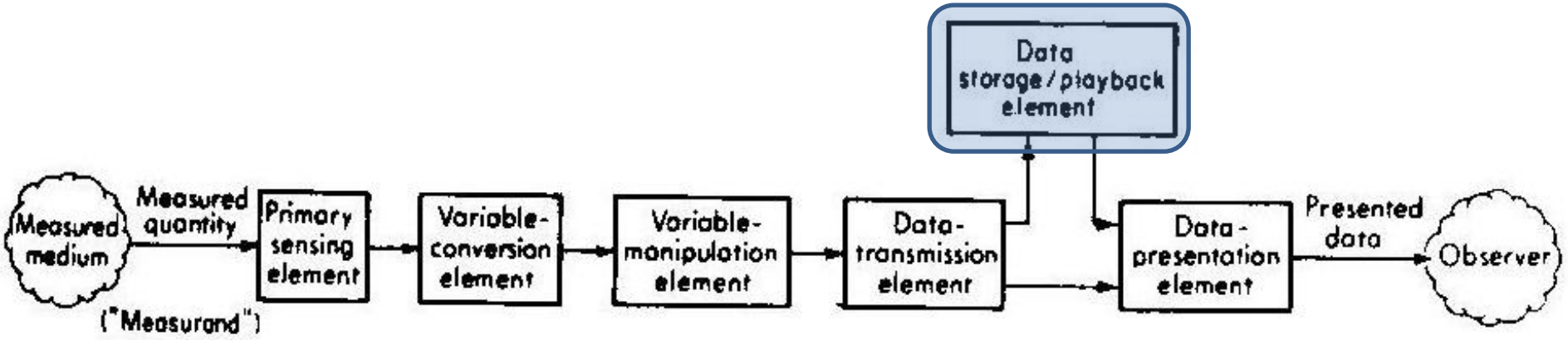
Variable manipulation element: This element will use a predefined mathematical operation. e.g. opamp

Functional elements of a measurement system



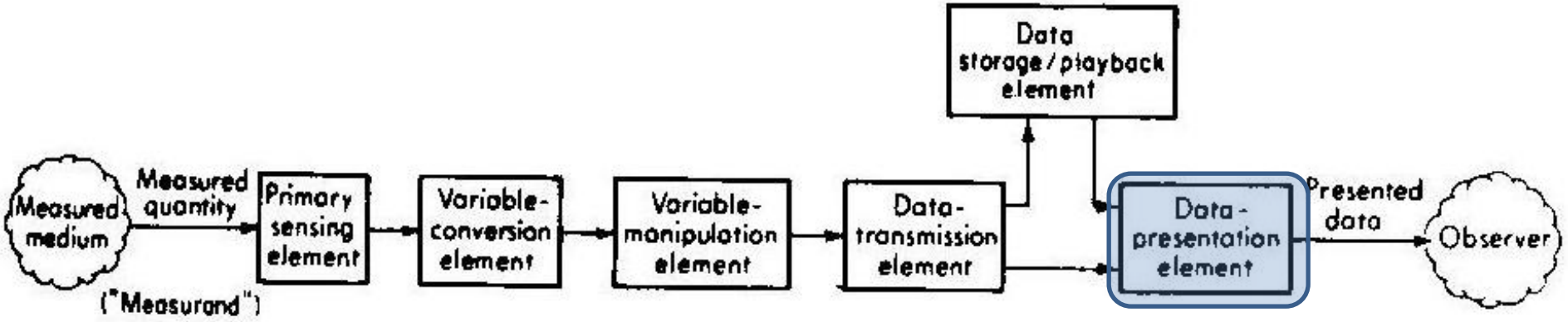
Data Transmission element: Primary sensing element and data storage or display may not be co-located. It could be simple wired or wireless.

Functional elements of a measurement system



Data Storage element: Data storage may be analog or digital. Used for analysis and archiving information

Functional elements of a measurement system



Data presentation element: User will typically need information in units relevant to measured medium (temperature, pressure, displacement etc.). Information is reconverted to present in the original units.

In a measurement system it is not necessary that all the elements are present and may not be in same sequence

Example - 1

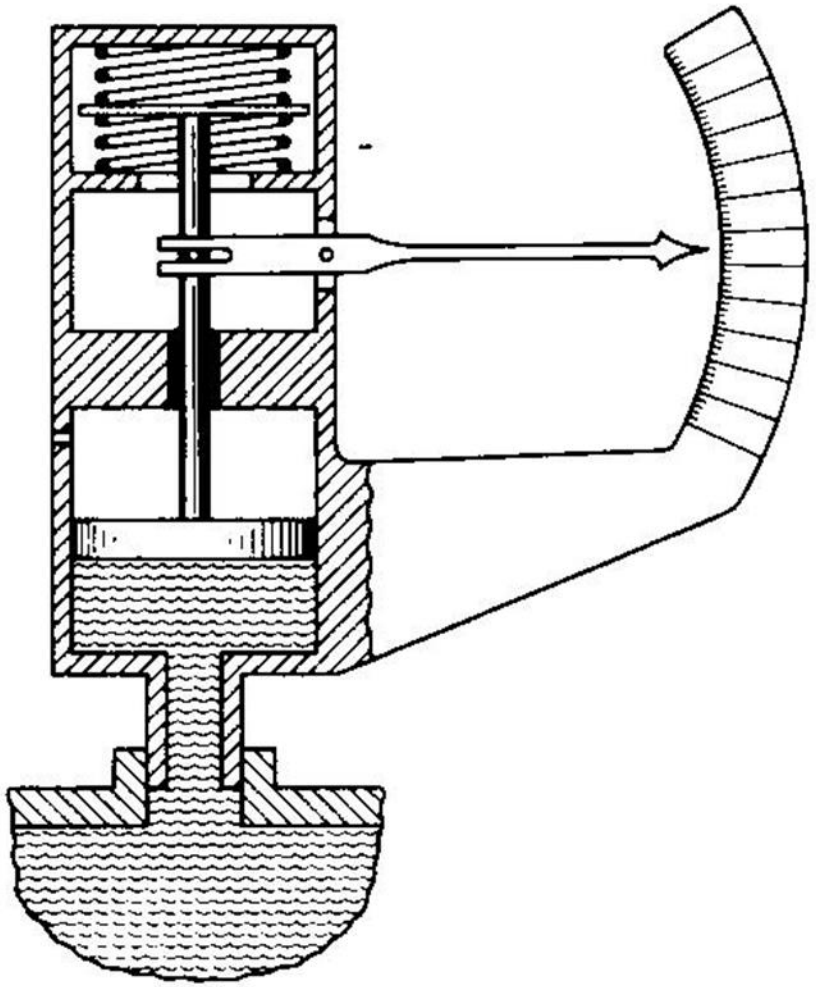
Piston – primary sensing element, variable conversion element (pressure to force)

Piston rod – Data transmission

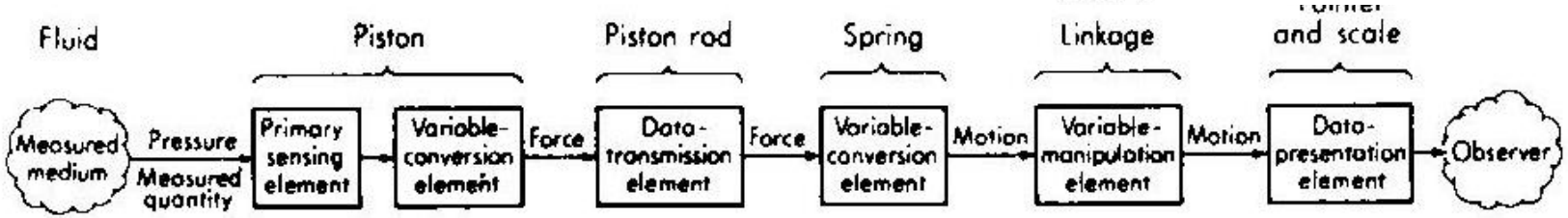
Spring – Variable conversion element : spring force is converted to linear motion

Linkage: Variable manipulation element: Amplification of the piston movement

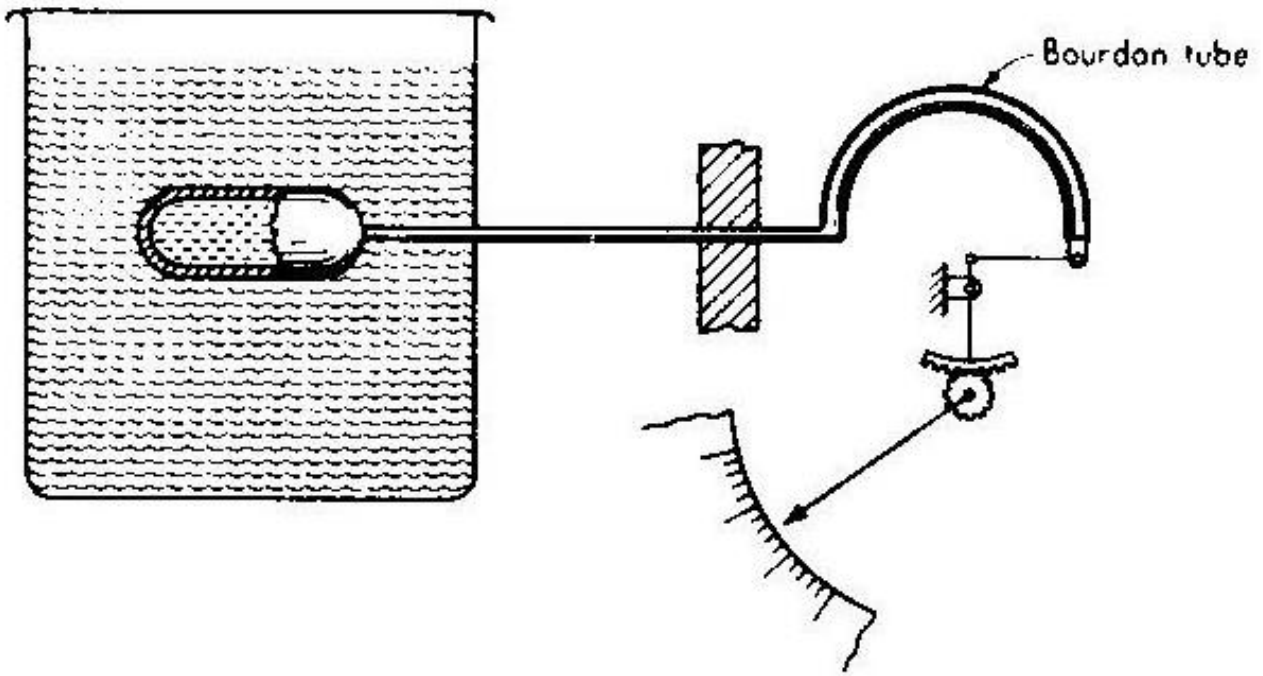
Pointer & scale : Data presentation element

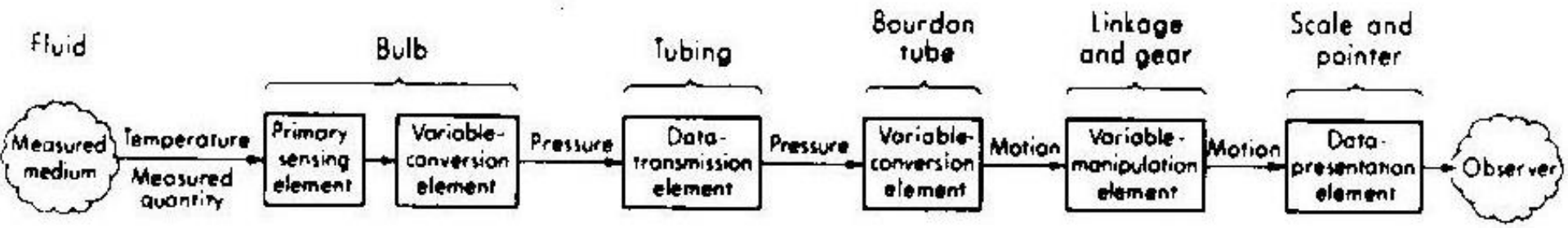


All the elements may not be present or may not be in sequence for all the instruments



Example - 2


Bourdon tube


Fluid
Bulb
Tubing
Bourdon tube
Linkage and gear
Scale and pointer
Measured medium
Temperature
Measured quantity
Primary sensing element
Variable-conversion element
Pressure
Data-transmission element
Pressure
Variable-conversion element
Motion
Variable-manipulation element
Motion
Data-presentation element
Observer

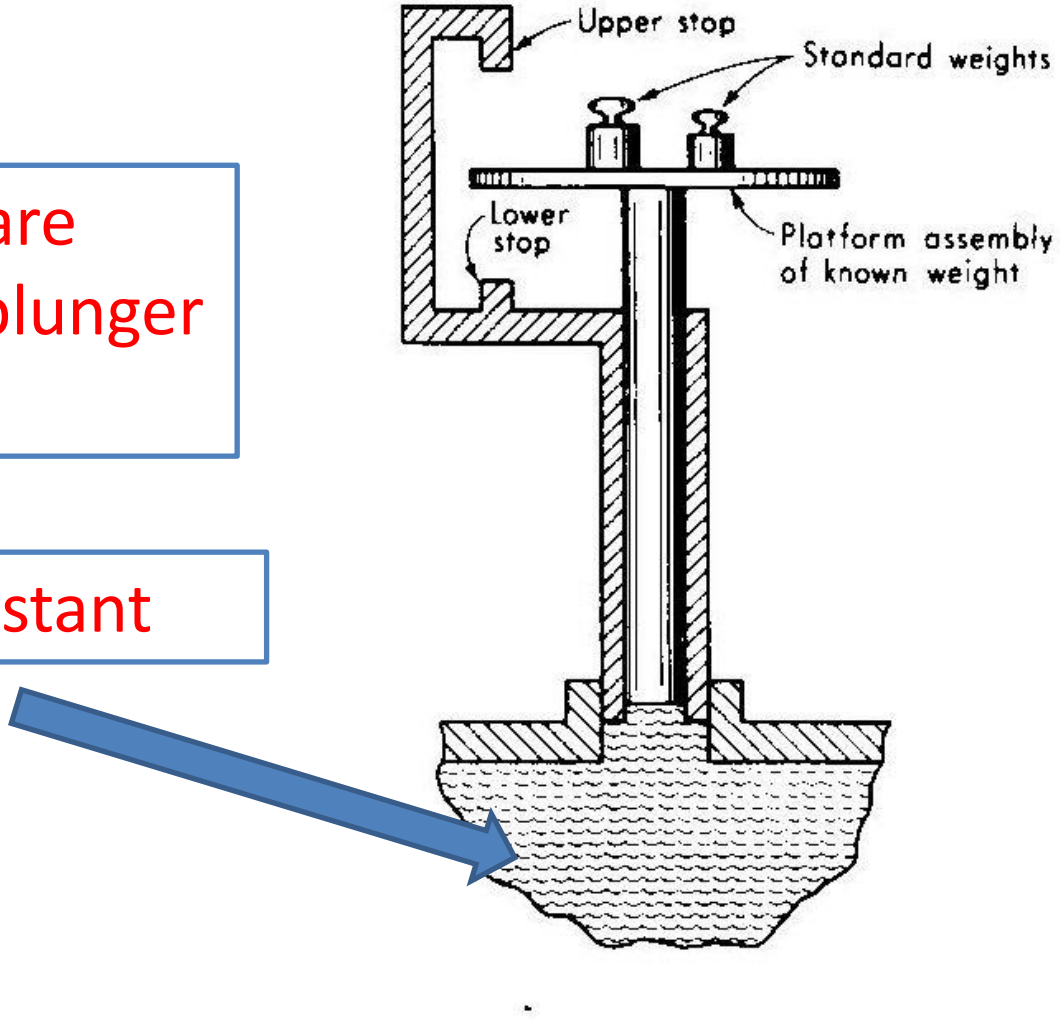
Null and Deflection methods

Wish to measure weight of unknown object?

Null and Deflection methods

Pressure gage: Weights are kept in such a way that plunger do not move

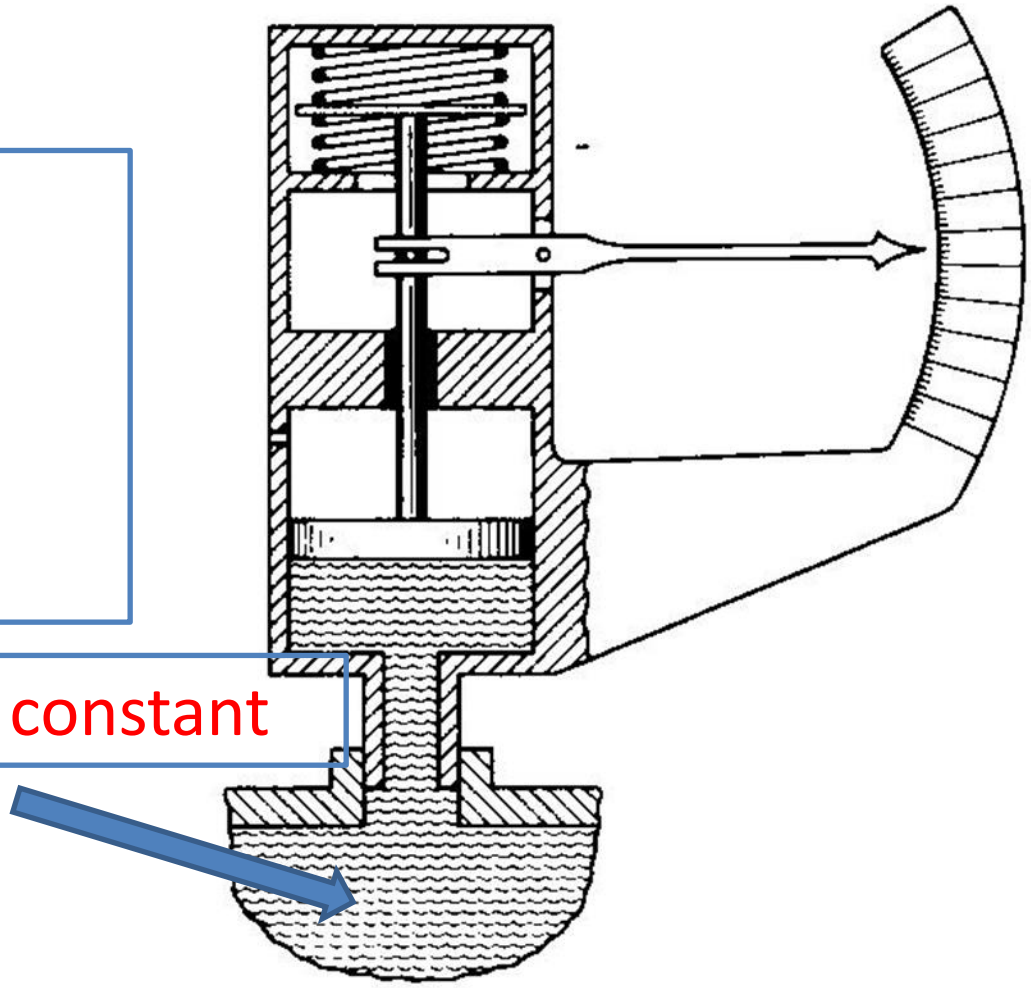
Volume will remain constant



Null and Deflection methods

Pressure gage: Force is balanced by spring deflection. Plunger movement rotates the indicator

Volume will not remain constant



Null and Deflection methods

Deflection type: Measured quantity produces some physical effect that causes some opposing effect in the system and which is balanced. The balance is achieved by deflection. Easier to use.

Null type: Device attempts to maintain deflection at zero by suitable application of an effect opposing that generated by the measured quantity. Measure quantity is inferred from the opposing effect. Requires feedback mechanism to balance. Generally used for precise and accurate measurements.