وزارة التعليم العالي والبحث العلمي
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قسم هندسة تقنيات القدرة الكهربائية

(1)

الاجهـــــزة والقيـــــاس

Measurement and Instruments

المرحلــة الثانيــة

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٢٠٢٠-٢٠٢١

Measurements and Instruments (اجهزة وقياسات)

1. References: المصادر

- Electrical and Electronic principles and technology by john bird.
- Alex book of Electrical technology by B.L THERAJA
  A.K the Raja

2. Measurements and errors.

Measurement (القياس)

Is a method or a procedure in which used Instruments to determine the stale of matter or variable quantity and help us to known the quantity or variable such us:

Current (I), voltage (v) capacitance (C) Temperature (t), length (L)

Dimensions quantities: Is the name which given to measurable quantity of exiting things.

Symbols of the base quantities as below:

Base quantities	symbol for quantity	symbol for dimes
Length	L, x, r, etc.	L
Mass	M	M
Time ,duration	T	T
Electric current	I, i	I
temperature	T	θ
Amount of substance	N	N
Luminous intensity	I v	J

And can be divided to.

(a) Fundamental unit: such as following

Quantity	Standard unit	symbol
Length	matter	M
Mass	Kilogram	Kg
Time	second	S
Electric current	ampere	A
temperature	kelvin	K
Luminous intensity	candela	Cd
matter	mole	mol

Unit and standard system.

There are two standard Units

a) International system of units (si):

Is a metric system are listed in following

System	Length	Mass	Time
M K S	Meter	Kilogram	second

Quantity	symbol
Length	Meter (m)
Mass	Kilogram (kg)
Time	second
Electric current	Amper (A)
Amount of substance	Mole (mol)

Brihrish system unit (fps):

system	length	Mass	Time
Fps	Foot	pound	second

	Standard unit	symbol	Deriviatia
Electric inductance	Henry	H	Vs /A
Electric conductance	Siemen	S	A / V
Resistivity	Ohm meter	Ω M	
Permihivity	Farad per meter	F/M	
permeability	Henry per meter	H/M	
Current density	Ampere per square meter	A/M^2	
Magnetic flux	Weber	Wb	Vs
Magnetic flux density	tesla	T	Wb/m^2
Magnetic field strength	Ampere per meter	A/M	
Frequency	hertz	Hz	S^{-1}
Luminous flux	lumen	Lm	Cd Sr
Luminance	Candela per square meter	Cd/m^2	
Illumination	Lux	Lx	Lm / m^2
Molar volume	Cubic meter per mol	M^3 /mol	
Molarity	Mol per kilogram	Mol/kg	
Molar energy	Joule per mol	J/mol	

b) Derived which is representd by the following table

	Standard unit	symbol	Derivation for
	Square meter	M^2	
	Cubic later	M^3	
	Meter per second	M / S	
	Meter per second squared	M / S^2	
	Joule	J	N M
	Joule per cubic meter	J / M^3	
	watt	W	J / S
	Watt per meter	W / M K	
	coulomb	C	A S
	volt	V	W / A
	Volt per meter	V / M	
	oha	Ω	V / A
	farad	F	As /V

Example1: write an expression for the electric charge in terms of Electric current in SI system with its dimensions.

Sol:

Current is the flow rate of charge

$$\Longrightarrow I = \frac{dQ}{dt} \rightarrow dQ = Idt \rightarrow Q = I\int_0^t dt = It$$

$$\rightarrow Q = Ampere.secand = A.sec$$

$$in\ dimensians, Q = [IT]$$

Example2: Express the Electric potential in SI system, and find its dimensions.

Sol:

Potential, v = work done per unit charge, (volt)

$$= \frac{Force\ \times distance}{current\ \times time} = \frac{mass\ \times acceleration\ \times distance}{current\ \times time}$$

$$= \frac{mass\ \times (\frac{velocity}{time})\ \times distance}{current\ \times time}$$

$$= \frac{mass\ \times [\frac{\frac{distance}{time}}{time}]\ \times distance}{current\ \times time}$$

$$= \frac{kg.[\frac{meter}{second^2}] \times meter}{Ampere \times second}$$

$$= kg.\frac{m^2}{A.sec^3} = kg.m^2.A^{-1}.sec^{-3}$$

In dimensions,

$$v = [ML^2I^{-1}T^{-3}]$$

Example3: find the SI units and dimensions of the Resistance.

Sol:

$$Resistance, R(ohm) = \frac{\rho\ell}{A} = \frac{\ell}{\sigma A} = \frac{v}{I}$$

Where

I: electric current, (A)

V: potential difference, (V)

ℓ: Length of the material, (m)

σ: The conductivity of the material, ($\mho/m$)

ρ: The Resistivity of the material, (Ω.m)

$$\sigma = \frac{1}{\rho}$$

A: the cross sectional area of the material, (m^2)

Now: starting from $R = \frac{v}{I}$,

$$R = \frac{v}{I} = \frac{work/charge}{current}$$

$$= \frac{Force * distance/(current \times time)}{current} = \frac{mass \times acceleration \times distance}{current^2 \times time}$$

$$= \frac{mass \times velocity \times distance}{current^2 \times time^2} = \frac{mass \times distance \times distance}{current^2 \times time^3}$$

$$= \frac{mass \times distance^2}{current^2 \times time^3} = \frac{kg\ m^2}{A^2 \times sec^3} = kg.m^2.A^{-2}.sec^{-3}, (ohm)$$

In dimensions, R= $[ML^2I^{-2}T^{-3}]$

Example 4: Find the Dimensions of the capacitance.

Note: for a parallel plate capacitor.

$$c = \in_\circ \in_r \frac{A}{d} = \frac{Q}{V}\ ,(forad)$$

Where $\in$ is the permittivity which is how much electrical field lines can pass through?

- For free space, $\in = \in_\circ = 8.854 \times 10^{-12}\ farad/meter$

A: is the area of plate

d: the distance between the plates .

$\in_r$: is the relative permittivity of a medium

But in general, $c = \frac{Q}{V}$

$$c = \frac{Q}{V} = \frac{charge}{work/charge} = \frac{coulomb^2}{work} = \frac{current^2 \times time^2}{force \times distance}$$

$$= \frac{current^2 \times time^2}{mass \times acceleration \times distance}$$

$$= \frac{current^2 \times time^3}{mass \times velocity\ \times distance} = \frac{current^2 \times time^4}{mass \times distance \times distance}$$

$$= \frac{current^2 \times time^4}{mass \times distance^2} = \frac{A^2.sec^4}{kgm^2} = kg^{-1}.m^{-2}.A^2 - sec^4$$

→The dimensions: $c = [M^{-1}L^{-2}I^2T^4]$. ,$(farad)$

Example 5: Derive the dimension and SI units for the electric field intensity. Knowing that the Electric field intensity is defined as the Electric force on unit charge, as well it represents the voltage rate of change with respect to distance.

Sol

$$E = \frac{dv}{dx} = \frac{V}{X} = \frac{F}{Q}\ (v/m)$$

$$= \frac{work/charge}{distance} = \frac{Force \times distance}{charge \times distance} = \frac{Force}{charge}$$

$$= \frac{mass \times acceleration}{current \times time} = \frac{mass \times velocity}{current \times time^2}$$

$$= \frac{mass \times distance}{current \times time^3} = \frac{Kgm}{Asec^3} = Kg.m.A^{-1}.sec^{-3}$$

And the dimensions:$[MLI^{-1}T^{-3}]$

Example 6: The electric force between two charges($Q_1 and\ Q_2$), separated by a distance r, is directly proportional to the product of the two charges, and inversely proportional

To the squared distance between them .If the proportional constant is K, express K in SI units and dimensions.

Sol

$F\ \alpha\ \frac{Q_! Q_2}{r^2} \rightarrow K\frac{Q_1 Q_2}{r^2} \rightarrow K = F\frac{r^2}{Q_1 Q_2}$

$\rightarrow K = mass \times acceleration \times \frac{distance^2}{charge^2}$

$\rightarrow$K= mass $\times \frac{velocity}{time} \times \frac{distance^2}{current^2 \times time^2}$

= mass $\times \frac{distance}{time^2} \times \frac{distance^2}{current^2 \times time^2}$ = mass $\times \frac{distance^3}{current^2 \times time^4}$

= kg $\frac{m^3}{A^2\ sec^4}$ = kg.m^3.A^{-2}.sec^{-4}

And in dimensions, k = [$ML^3I^{-2}T^{-4}$]

Note that F= $\frac{Q.Q_2}{4\pi r^2}$, and the units of $\frac{1}{k}$ is the same dimensions of permittivity which is [$M^{-1}L^{-3}L^2T^4$].

Example: what are the fundamental units of the frequency?

Sol:

Frequency (in Hertz) is the number of cycles in one second

$\rightarrow$f = $\frac{Cycles}{Second}$ = $\frac{1}{Sec}$ = sec^{-1}

In dimensions, f=[T^{-1}]

Note that constants (numbers) are without units (unit less).

Multiplication Factors of units

The multiples and submultiples of a units are written by adding suitable multiplication factor as prefix to the unit.

The names and symbols of various multiplication factors are shown in the following table:

Multiplication Factor	Name	Symbol
10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	Kilo	K
10^{2}	Hecto	H
10	Deco	da
10^{-1}	Deci	d
10^{-2}	Centi	c
10^{-3}	Milli	m
10^{-6}	Micro	μ
10^{-9}	Nano	N
10^{-12}	Pico	t
10^{-15}	Femto	F
10^{-18}	atto	a

* Three main systems of units (standards), in summary, are below,

System	Length	Mass	Time
FPS	Foot	Pound	Second
CGS	Centimeter	Gram	Second
*MKS	Meter	Kilogram	Second

MKS is the SI system.

Importance of Measuring Instruments

The importance of measurements can be noticed by anybody in everyday life. Measurements are the basis for the understanding of all kinds of deals. The trade of goods is entirely based on well- Known quantities.

Measurement of absolute standards are extremely complicated and time-consuming. Therefore Secondary standards are used to be more convenient in calibrating other quantities. These secondary standards are checked periodically in comparison with absolute standards.

Examples (H.W):

2. Define Fundamental units and derived units.
3. What is SI system?
4. List the fundamental quantities in SI system.
5. Write the multiplication factors for 1000, 100000, 1000000, and 1/1000.

6. Convert the following:

- 10 KV into volts.
- 50 MW into kilo watts,
- 25 kohms to ohms,
- 75 milli Amps to Amperes,

Various Electrical Instruments and their Functions:

In the field of Electrical Technology, several electrical quantities are to be measured. The measurement of various electrical quantities will help the technician/user to monitor the performance of electrical equipment or system. If measured value is different than the rated value, there may be a fault in the equipment/system or any other cause of error.

Various parameters of an equipment to be monitored and measured frequently in order to improve the system and to avoid any fault/ accident before it occurs.

The following are Basic Electrical Instruments and their functions:

Electrical Instrument	**Electrical Quantily**	**Units**
Voltmeter (V)	Voltage (V)	Volts (V)
Ammeter (A)	Current (I)	Amps (A)
Watt meter (W)	Power (P)	Watts (W)
Energy meter (Kwh)	Energy (E)	Unit, Kwh
Ohm meter	Resistance (R)	Ohms (Ω)
Multimeter (AVO)	Current, Voltage,	Amps, Volts, ohms
	Resistance	Ohms
Frequency meter	Frequency (f)	Hertz (Hz)
Tachometer	Speed of motor	revolutions per
		Minute (rpm)
Clamp meter	Current (I)	Amps (A)
Megger	Resistance (R)	Mega ohms

Example: If the measured output voltage is increased by 100mv for a temperature change of 40°C. What is the sensitivity?

Sol:

Sensitivity= $S= \Delta V/\Delta T= 100\ mv/4°C= 25\ mv/°C$

Example: An Electrical Circuit has a resistor chosen of True value 1000 this resistor?

Sol: measured value= true value ± tolerance= 950 Ω, and 1050 Ω

Example: A car speedometer has subdivisions of 20 Km/h, and the lower speed can be estimated accurately is 5 Km/h. what is the Resolution have?

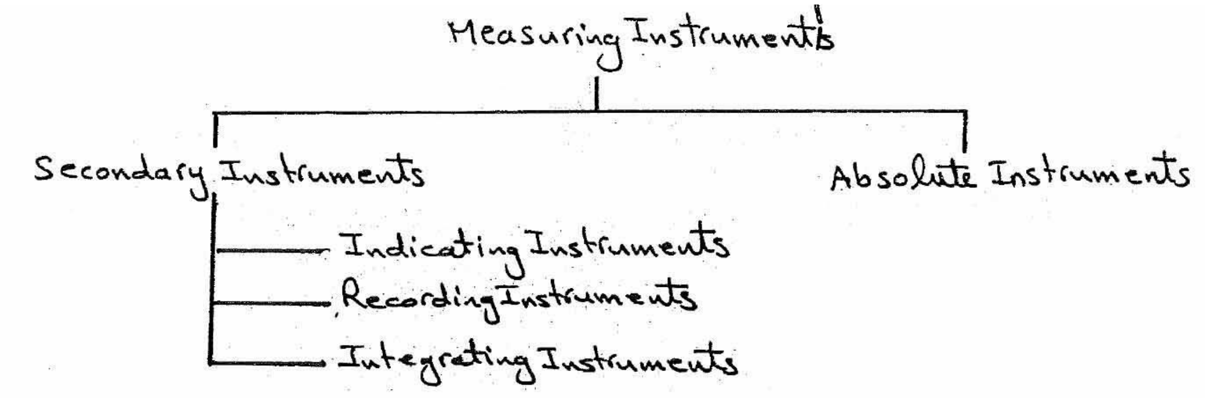
Sol Resolution is 5 Km/h

Example (H.W):

Name any four Electrical instruments and their Functions.

Classification of Measuring Instruments

The Electrical measuring Instruments can be classified as following



Absolute Instruments

Absolute instruments show the quantity to be measured in terms of instrument constant and its deflection, and they require no comparison with any other standard instruments.

Tangent Galvanometer, Raleigh current and absolute electrometer are examples of absolute instruments. They are mostly used in laboratories as Standardizing instruments.

Secondary Instruments:

Secondary instruments are those which give the value of the quantity on its scale or its display unit directly by a pointer. The scale is calibrated by comparison with absolute instruments. Most of the measuring instruments, which are generally used are of secondary type.

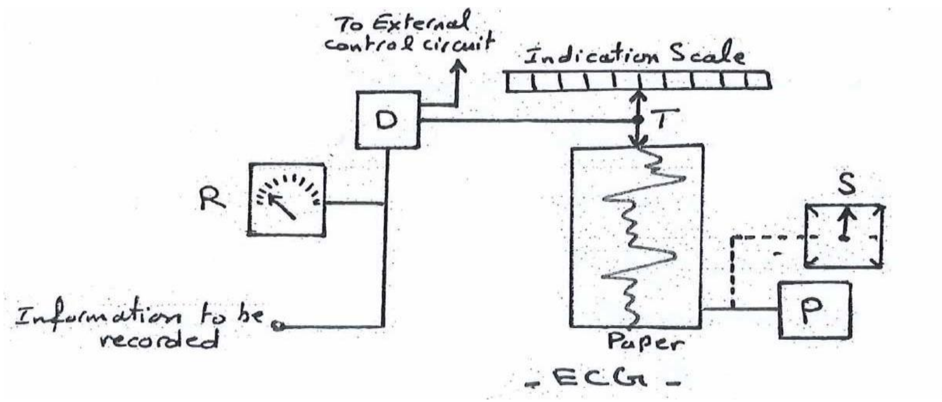
The ordinary Voltmeter, Ammeter, Energy meter are example for secondary instruments.

Indicating Instruments

Indicating instruments are those which indicate the magnitude of the instantaneous value being measured by means of a pointer over a calibrated scale. The indication. Of pointer also change with respect to time, giving no scope to know the previous value. Ammeter, voltmeter, wattmeter, frequency meter, power factor meter, etc… fall under this category.

Recording Instruments

The instruments which are not only read the instantaneous value but also make a record continuously is called recording instrument. The magnitude of the quantity is recorded on a paper for certain period of time. In such instruments, the moving system carries an inked pen which touches lightly a sheet of paper wrapped roundover a uniformly rotating dium.

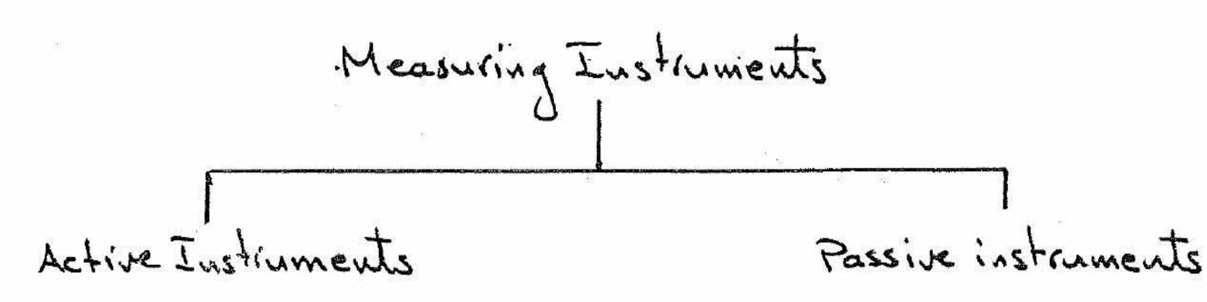


These instruments are generally used where continuous informations is required about the changes in magnitude of the electrical quantity, such that to keep them within well specified limits.

Integrating instruments

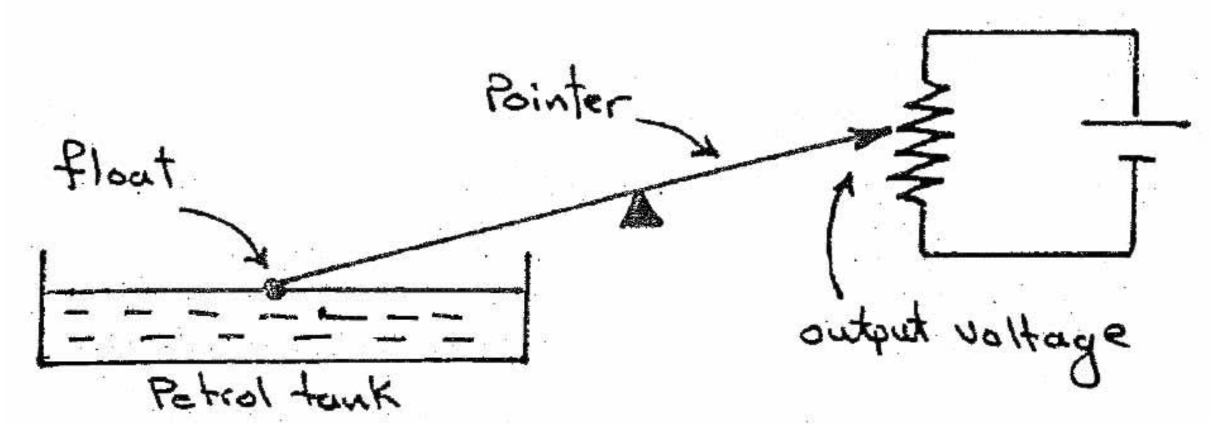
These instruments measures and registers the total quantity of electricity in a circuit over a specified time. It gives a cumulative value of electrical quantity. Examples: Ampere- houre meter, Energy meter.

The output signal of the instruments are sometimes adapted. To external power source, and sometimes are not. Therefore, we can classify the instruments also as following:



Active instruments

The quantity being measured simply modulates (adapts to) the magnitude of some external power source. Example, float- type petrol tank level indicator.

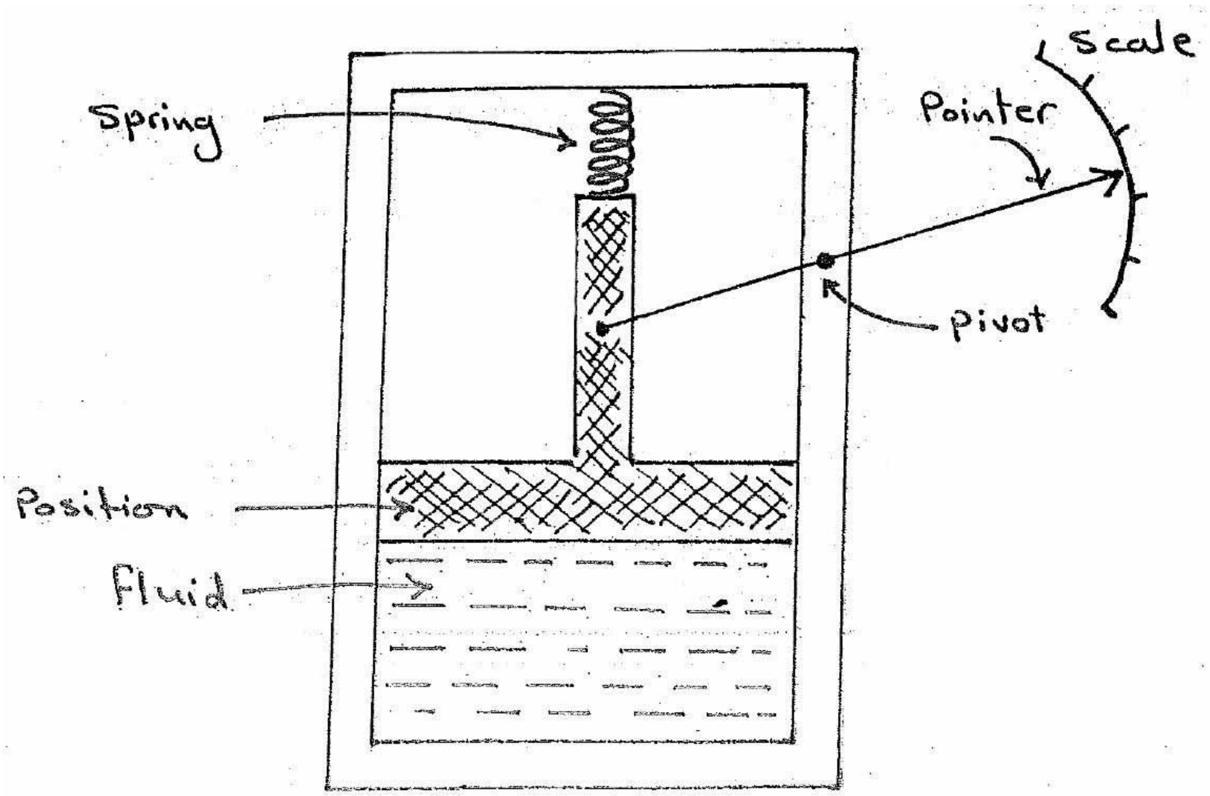


The change in petrol level moves a potentiometer arm, and the output signal consists of a proportion of the external voltage source applied across the two ends of the potentiometer. Note that the energy in the output signal comes from the external power source.

Passive instruments

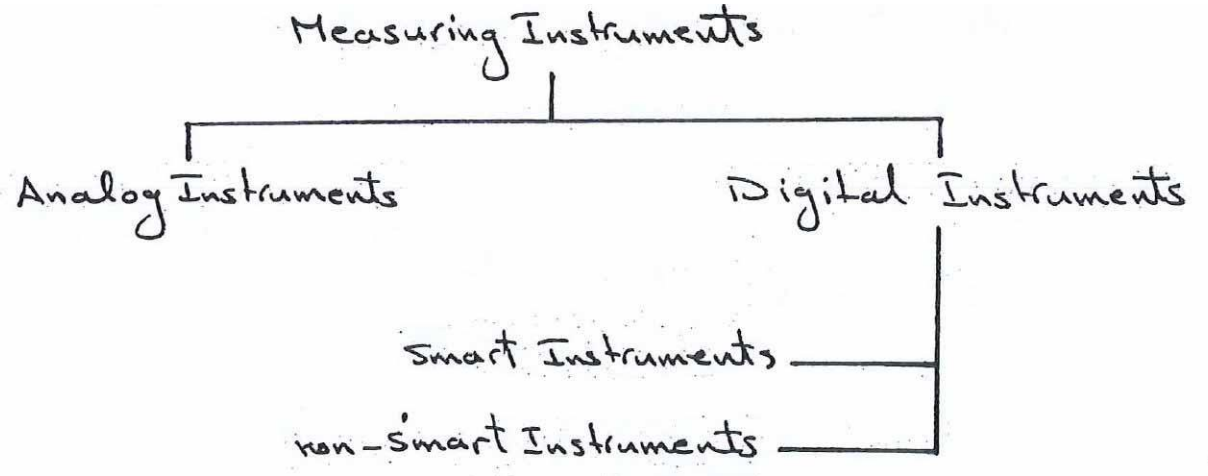
The instrument output is entirely by the quantity being measured. The difference between active and passive instruments is the level of measurement resolution that can be obtained.

Example: pressure- measuring device.



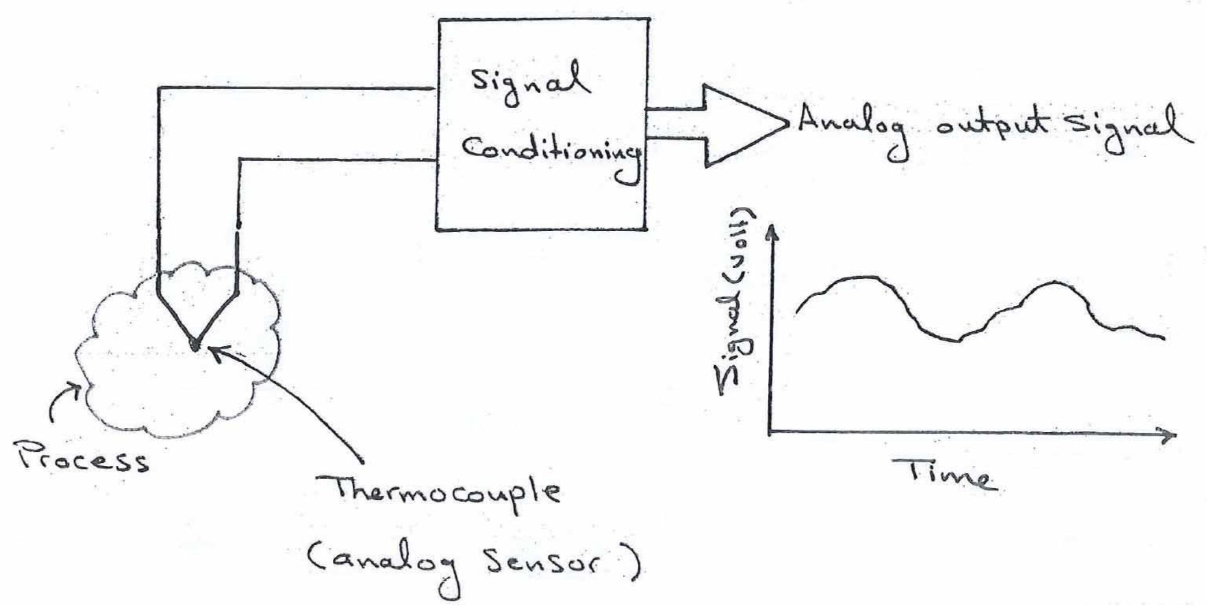
The pressure of the fluid is translated into a movement of a pointer agonist scale. The energy expanded in moving the pointer is derived entirely from the change in pressure measured; No other energy inputs to the system.

We can classify the measuring instruments according to the signal processing and type.



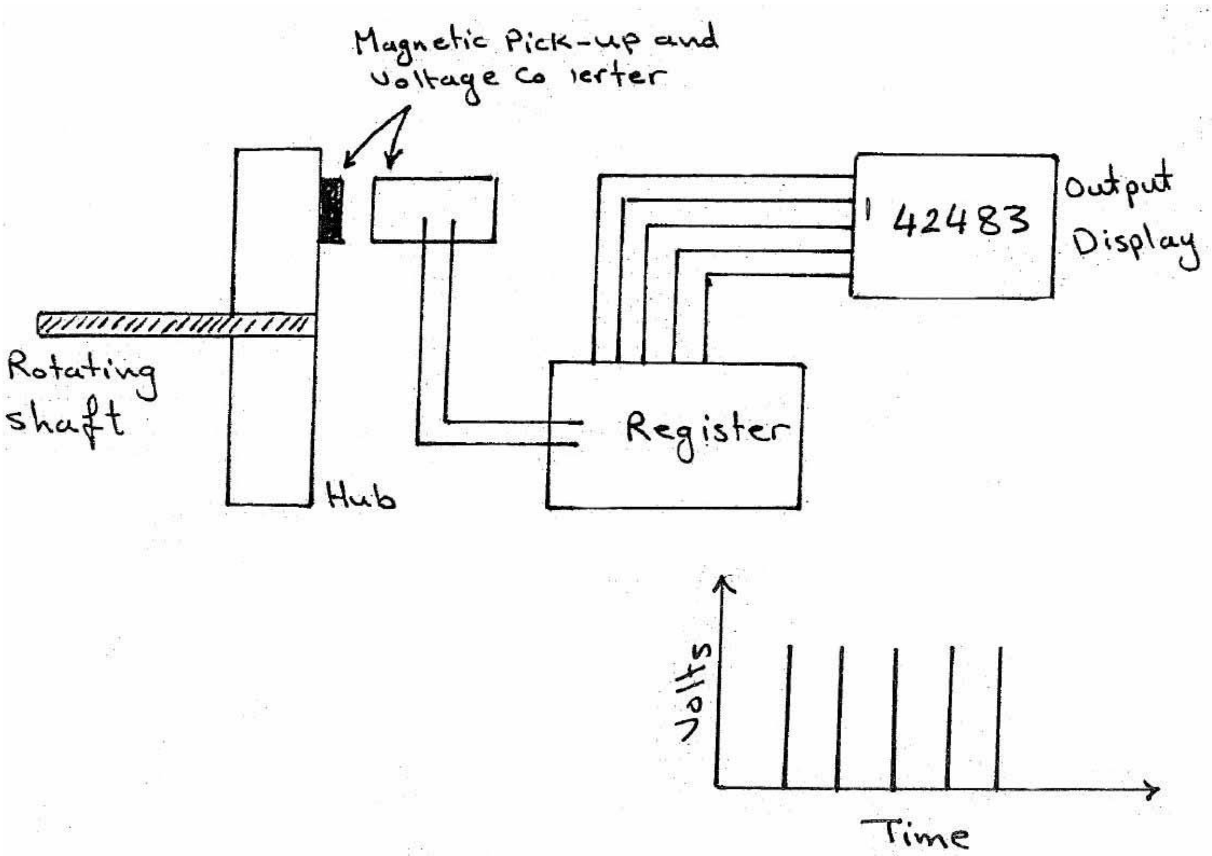
Analog instruments

An analog instrument gives an output that varies continuously as the quantity being measured. Example is the Deflection- type of pressure gauge.



Digital instruments

A digital instrument has an output that varies in discrete steps and only have a finite number of values; example is the Revolution counter.



Smart instruments

An instrument with a microprocessor to do some operations during and after measurements.

Non- smart instruments

Those digital instruments not involving a microprocessor.