SECTION A

UNITS, STANDARDS AND ERRORS

Measurement

- **Measurements** are the basic means of acquiring knowledge about the parameters and variables involved in the operation of a physical system.
- Measurement generally involves using an instrument as a physical means of determining a quantity or variable.
- An instrument or a measuring instrument is, therefore, defined as a device for determining the value or magnitude of a quantity or variable. The electrical measuring instrument, as its name implies, is based on **electrical principles** for its measurement function.

Types of instrument

- These days a number of measuring instruments, both **analog** as well as **digital** ones, are available
- For the measurement of electrical quantities like voltage, current, power energy, frequency, power factor, etc. In analog devices the output or display is a continuous-time signal and bears a fixed relationship to the input.

Types of Analog Instruments

- Analog instruments may be divided into three groups:

(a) **Electromechanical instruments**

(b) **Electronic instruments**

(c) **Graphical instruments**

Some Useful Definition

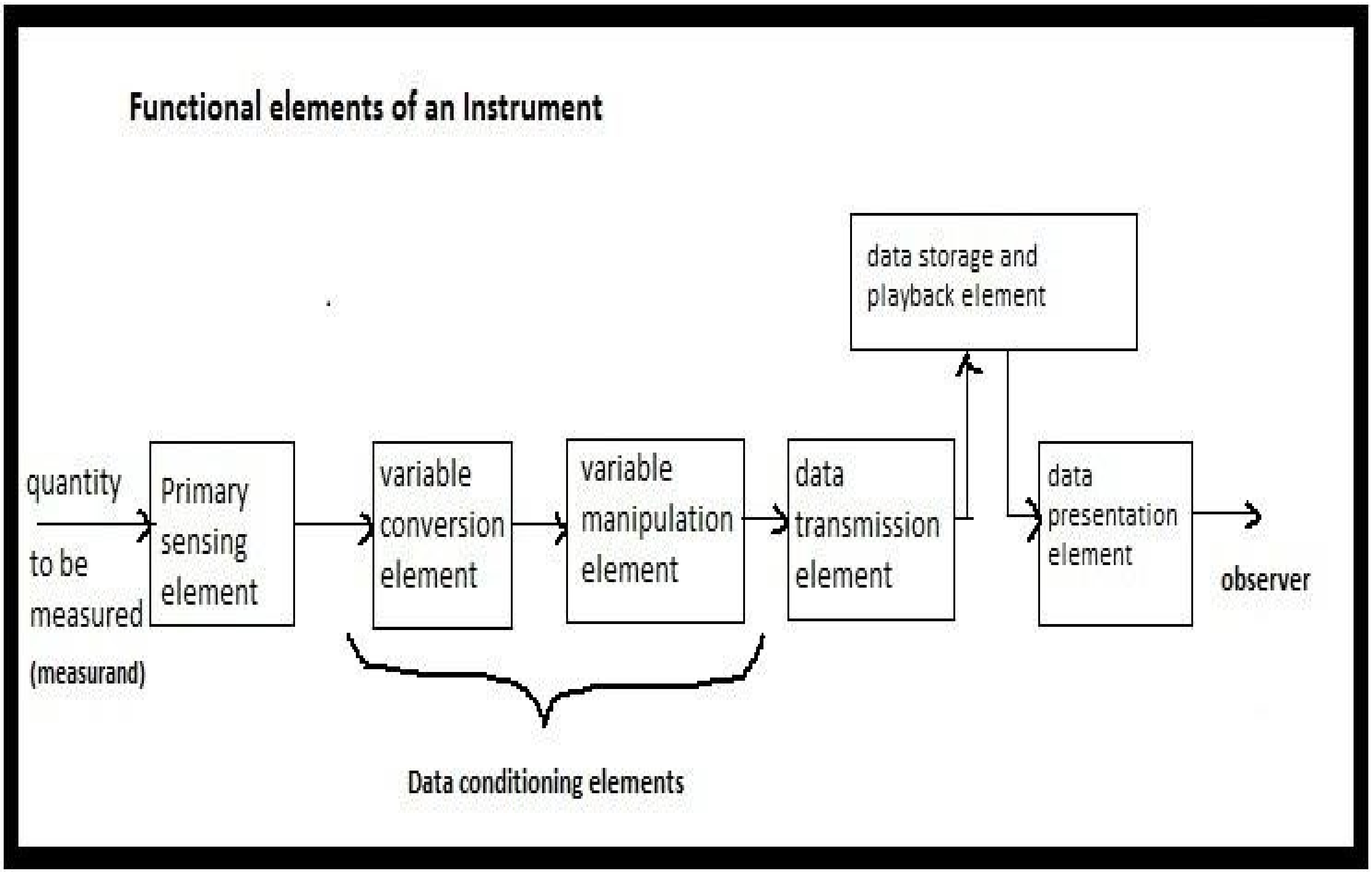
Measurement work employs a number of terms which are defined below:

- **Measurand**: The quantity or variable being measured is called measurand or measurement variable.
- **Accuracy:** It is defined in terms of the closeness with which an instrument reading approaches the true or expected (desired) value of the variable being measured.
- **Precision:** It is measure of the consistency of reproducibility (repeatability) of the measurement (i.e., the successive reading do not differ). For a given fixed value of an input variable, precision is a measure of the degree to which successive measurement differ from one another.

contd.....

- **Sensitivity**: It is defined by the change in the output or response of the instrument for a unit change of input or measured variable.
- **Resolution** : Resolution is the smallest change in a measured variable (or measurand) to which the instrument will respond.
- **True or Expected Value**: The true or expected value of a quantity to be measured may be defined as the average of an infinite number of measured values when the average deviation due to the various contributing factors tends to zero. It also refers to a value of the quantity under consideration that would be obtained by a method (known as exemplar method) agreed upon by experts. In other words, it is the most probable value that calculations indicate and one should expect to measure.

Generalized block diagram



Standard Classification

- International Standards
- Primary Standards
- Secondary Standards
- Working Standards

Contd....

- **Error: It is the deviation of the measured (or indicated) value from the true (or expected) value of a quantity. In other words, error is the difference between the measured value and the true value of the unknown quantity. Then error of measurements is given by**

$$\in A = A_m - A_t$$

where A_m= Measured value of the quantity

A_t= True value of the quantity

Types of Error

GROSS ERROR: This class of error mainly covers human mistake. Gross errors may be of any amount so mathematical analysis is impossible.

SYSTEMATIC ERROR

Instrumental Errors

Inherent shortcomings of Instrument

Misuse of Instruments

Loading effect

Environmental Error

Observational Error

Random Error

Types of error measurement

Absolute error $|\in_0| = \max |A_m - A_t|$

Relative error $\in_R$ is given by

$\in_R$ = Absolute error\True value

$= \in_0 / A_t$

$= (A_m - A_t) / A_t$

Contd....

The **percentage relative error** $\% \in R = \in R \times 100.$

Bandwidth: The bandwidth of an instrument relates to the maximum range of frequency over which it is suitable for use. It is normally quoted in terms of 3 dB(dB= decibel) point.

Forces acting on electromechanical device

It is essential that the moving system is acted upon by three distinct torque (or forces) for satisfactory working. There torques are:

1. A deflecting or operating torque, Td

2. A controlling torque, Tc

3. A damping torque, Tv

Contd....

Deflecting (Or the Operating) Torque

The deflecting torque, causes the moving system of the instrument to move from its zero position. It may be produced by utilizing any one of the effects of current or voltage in the instrument such as magnetic effect, electromagnetic induction effect, heating effect, electrostatic effect etc.

The deflecting torque has to supply the following torque-components presents in an instrument The **torque required to overcome the torque due to the inertia of the system**.

Controlling Torque

The controlling torque developed in an instrument has two functions:

(a) It limits the movement of the moving system and ensures that the magnitude of the deflections always remains the same for a given value of the quantity to be measured.

(b) It brings back the moving system to its zero position where the quantity being measured is removed or made zero.

That is, for a **steady deflection**,

Controlling torque, T_c= Deflection or operating torque, T_d

Types of controlling torque

The controlling torque is entered in all commercial instruments by any one of the following

three ways.

- By means of one or two coiled springs. The corresponding instrument is termed spring controlled instruments(mostly used system).
- By the action of gravity due to suitably placed weights on the moving system. Such instruments are known as gravity controlled instruments.
- Permanent Magnet

Spring Control

Let E be the young-modulus for the material of the spring and θ(radians) be the deflection of the moving system to which one end of the spring is attached. Then, the controlling torque developed in the spiral spring is given by

$$T_c = \frac{Ebt^2}{12l}\,\theta$$

or $T_C = k_s\,\theta$

spiral spring is given by

$$T_c = \frac{Ebt^2}{12l}\,\theta$$

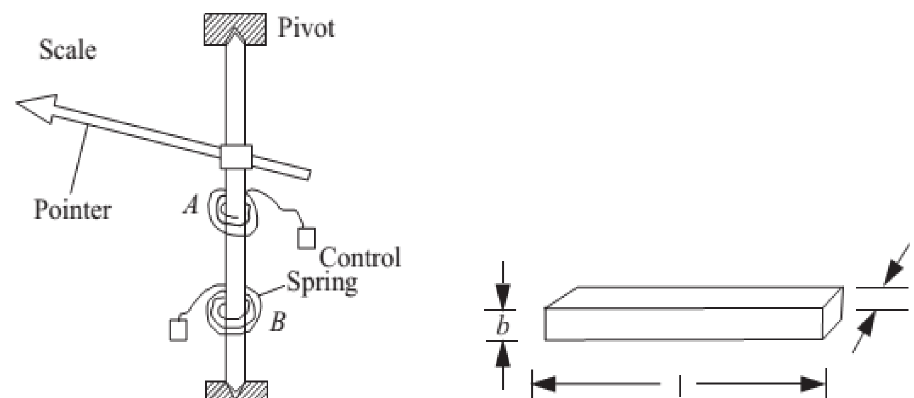
or $T_C = k_s\,\theta$

where l= Total length of spring strip (m)

b= depth of the strip (m)

t= thickness of the strip (m)

ks= spring constant



(a) Pivoted-moving system with spring control

(b) Spring in strip form

SCALING IN SPRING CONTROL

Then for spring control instrument, the controlling torque, TC, is

$T_c = K_s \theta$ ...(12.15)

The pointer comes to rest when the deflecting torque (Td) and the controlling or restoring torque (Tc) are equal, i.e., Td is equal and opposite to Tc.

At equilibrium, $T_d = T_c$

Therefore, $KI = K_s \theta$

$\therefore I = K_s \theta / k$

This equation shows that the current is directly proportional to the deflection and since

Eqn. (12.16) is a linear relation, the scale with spring controlled instrument for deflecting

torque given by Eqn. (12.14) will be uniform throughout the scale.

Gravity Control

In gravity controlled instruments, a small adjustable weight is attached to the
spindle of the moving system such that the deflecting torque produced by the instrument has to act against the action of gravity. Thus a controlling torque is obtained. This weight is called the control
weight. Another adjustable weight is also attached is the moving system for zero adjustment and balancing
purpose. This weight is called Balance weight.

When the control weight is in vertical position as shown in Fig. 12.2 (a), the controlling torque is
zero and hence the pointer must read zero. However, if the deflecting torque lifts the controlling weight
from position Ato Bas shown in Fig.12.2 (b) such that the spindle rotates by an angle θ, then due to
gravity a restoring (or controlling) torque is exterted on the moving system.

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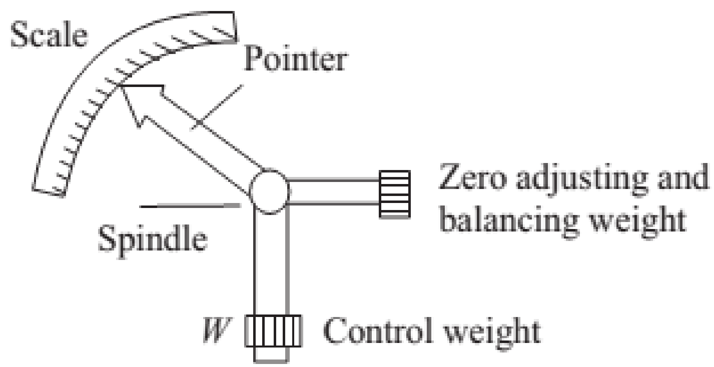
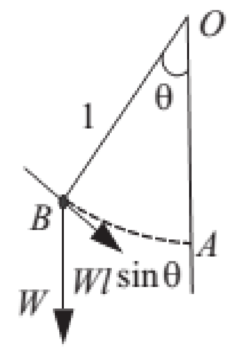


(*a*) Gravity controlled moving system at zero deflection



(*b*) Moving system rotated by θ radian

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The controlling (or restoring) torque, Tc, is given by

$Tc = Wl\sin\theta = kg\sin\theta$

where Wis the control weight; lis the distance of the control weight from the axis of rotation of the moving system; and kg

is the gravity constant.

Equation shows the controlling torque can be varied quite simply by adjustment of the position of the control weight upon the arm which carries it.

Again, if the deflecting torque is directly proportional to the current, I i.e.,

$Td = kI$ ...

We have at the equilibrium position

$Td = Tc$ or $kI = kg\sin\theta$ or $I = Kg/K \sin\theta$

Contd…

This relation shows that current Iis proportional to sin θ and not θ. Hence in gravity controlled

instruments the scale is not uniform. It is cramped for the lower readings, instead of being uniformly

divided, for the deflecting torque assumed to be directly proportional to the quantity being measured.

Advantages of Gravity Control

1. It is cheap and not affected by temperature variations.
2. It does not deteriorate with time.
3. It is not subject to fatigue.

Disadvantages of Gravity Control

1. Since the controlling torque is proportional to the sine of the angle of deflection, the scale is
not uniformly divided but cramped at its lower end.
2. It is not suitable for use in portable instruments (in which spring control is always preferred).
3. Gravity control instruments must be used in vertical position so that the control weight may
operate and also must be leveled otherwise they will give zero error.
In view of these reasons, gravity control is not used for indicating instruments in general and
portable instruments in particular.

Damping Torque

We have already seen that the moving system of the instrument will tend to move under the action of the deflecting torque. But on account of the control torque, it will try to occupy a position of rest when the two torques are equal and opposite. However, due to inertia of the moving system, the pointer will not come to rest immediately but oscillate about its final deflected position and takes appreciable time to come to steady state. To overcome this difficulty a damping torque is to be developed by using a damping device attached to the moving system. The damping torque is proportional to the speed of rotation of the moving system, that is $T_v = k_v \, d\theta/dt$

where k_v= damping torque constant

$d\theta/dt$= speed of rotation of the moving system

Depending upon the degree of damping introduced in the moving system, the instrument may have any one of the following conditions as depicted in fig-

- 1. Under damped condition: The response is oscillatory
- 2. Over damped condition: The response is sluggish and it rises very slowly from its zero position to final position.
- 3. Critically damped condition: When the response settles quickly without any oscillation, the system is said to be critically damped.

In practice, the best response is slightly obtained when the damping is below the critical value i.e.,the instrument is slightly under damped

Supporting the Moving Element

- The force or torque developed by the moving element of an electrical instrument is necessarily small in order to keep the power consumption at low level.
- With the operating forces being small the frictional forces must be kept to a minimum in order that the instruments reads correctly.

Types of Support

- Suspension:
- Taut Suspension:

Two flat metal ribbons are made of phosphor bronze and platinum alloy are held under tension by springs to support the coil. Because of the springs the metal ribbons behave like rubber under tension. The ribbons also exert a controlling force as they twist and they can be used as electrical connections to the moving coil.

Used in Galvanometer type instruments

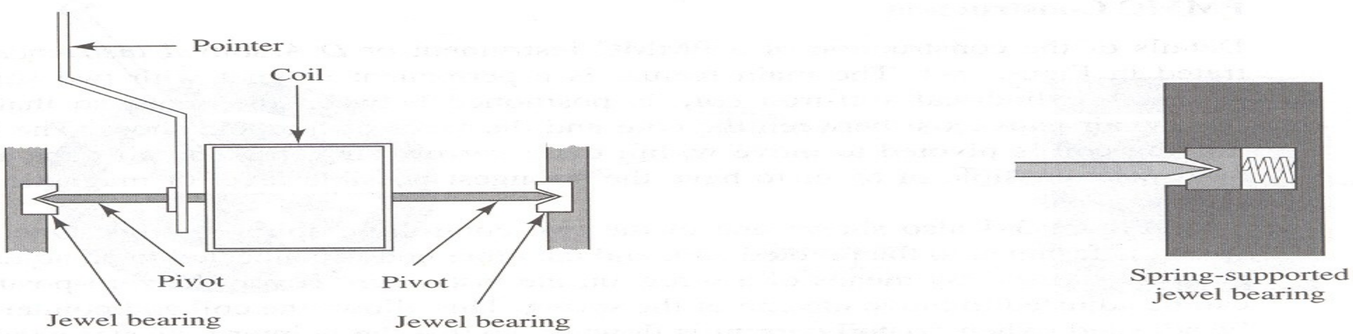
Pivot and jewel bearings:

The moving system is mounted on a spindle made of hardened steel. The two ends of the spindle are made conical and then polished to form **pivots**. These ends fit conical holes in the jewels located in the fixed part of the instrument. These jewels are made of sapphire. This allows the coil to rotate freely with least possible friction because it has found that the frictional torque, for jewel bearings is proportional to the contact area between the pivot and jewel. Pivot have radius .0125mm to0.75 mm w.r.t the weight and force applied.

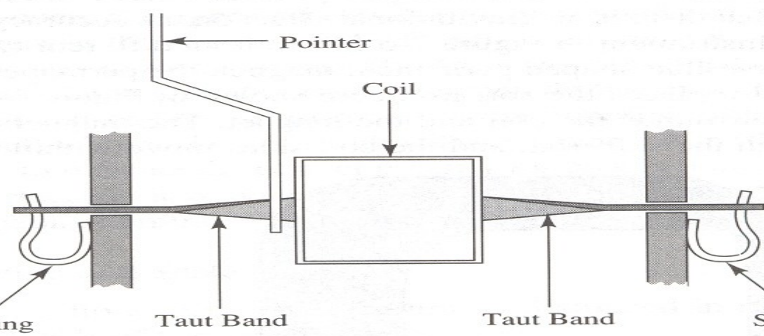
Comparison of supports

- Because there is less friction taut band suspensions are can be made more sensitive than the pivot one. The most sensitive jewel bearing gives FSD with a coli current of 25 microampere but in taut suspension FSD may be achieved with coil current 2 microampere.
- Taut band instruments are extremely rugged.

Pivot and jewel bearing and Taut Band Suspension



(a) Pivot and jewel-bearing suspension



(b) Taut-band suspension

Figure 3-3 The moving coil in a PMMC instrument may be supported by pivots in jeweled bearings, or by two flat metal ribbons held taut by springs. Taut-band suspension is the toughest and the most sensitive of the two.

Scale Information

Instrument scales and pointers may be considered together in two classes:

(i) Those intended for reading quickly(in case of switchboard instruments at a distance)

(ii) Those intended for close accurate reading

Features of pointer

- The weight and inertia of pointer must be reduced so as to reduce the load on the bearing and to avoid excessive damping torque.
- The pointer motion is limited by buffers or stops to a little more than the scale. These stops are constructed as very light springs so that the pointer is not bent when it strikes them sharply on a sudden overload or reversal of the operating current.

Pointers and Scales

Pointers and scales of instruments may be classified together into two groups:

- Instruments used for reading at considerable distance.
- Instruments used for precisions work at shoot range.

It is essential that the pointer must be light and must have small inertia constant so as to reduce the load in the bearing of the moving system and to avoid high degree of damping. Its outline must be bold

with sharp pointer in the first type. We often use aluminium strip on tube for the pointer. The scale of an instrument of first category is mostly printed on the enameled surface of a metal plate, or on paper or card-board cemented rigidly to a metal backing plate. For the precision (work) in reading, a strip of mirror is mounted in an opening in the scale beneath the pointer. The reading is taken by removing the parallax error between the position and its image in the mirror.

Cases:

The main function of a case is to make the instrument dust and moisture proof. Steel cases are used to provide magnetic screening for instrument which are affected by external magnetic fields. To reduce the error due to hysteresis and eddy currents effects, the moving system of instruments should be mounted in a position far away from the metal case.

Switch board and panel instrument

This instruments have a square or rectangular front. The pointers and scales for these instruments should be so that the position of the pointer is conspicuous, the scale markings are legible and there is contrast with background. Pointers are usually broad or carry broad targets as their ends. Aluminium strip or tube is used for making pointers.

The scale is generally printed on the enameled surface of a metal plate or on paper or card board pasted to a metal plate. Scale markings are usually broad.

Portable instruments

Portable instruments usually have knife edge pointer moving over scale marked with fine lines, formed by flattening the end of a light aluminium tube. If the pointers and the scales are in different planes, observational errors may result on account of parallax. The errors due to parallax rise due to the planes, observational errors may result on account of parallax. The parallax errors can be avoided by using knife edge pointers and scales mounted in the same plane as the tip of the pointer.