Chapter1

Overview of Instruments for electrical and non-electrical measurements

Objective

- At the end of this chapter, students should be able to:
  1. Subdivide instruments into separate classes according to several criteria.
  2. broadly establish several attributes of particular instruments such as accuracy, cost, and general applicability to different applications.

1. INTRODUCTION

- Measurement is the process of determining the amount, degree or capacity by comparison with the accepted standards of the system units being used.

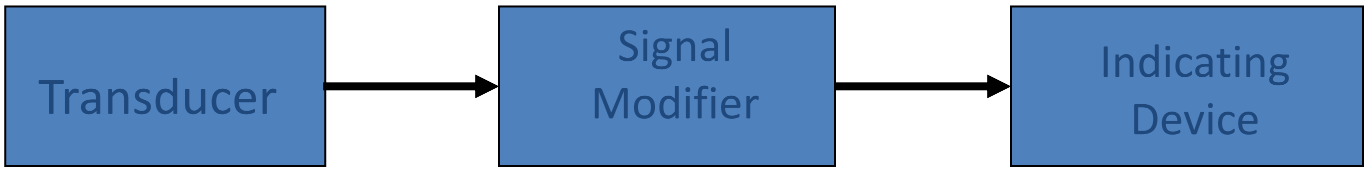
- Instrumentation is a technology of measurement which serves sciences, engineering, medicine etc.

- Instrument is a device for determining the value or magnitude of a quantity or variable.

- Electrical instrument is based on electrical or electronic principles for its measurement functions.

BASIC ELECTRICAL INSTRUMENT

- Basic elements of an electrical instrument



1) Transducer

    - convert a non electrical signal into an electrical signal

2) Signal modifier

    - convert input signal into a suitable signal for the indicating device (e.g amplifier)

3) Indicating device

FUNCTIONS

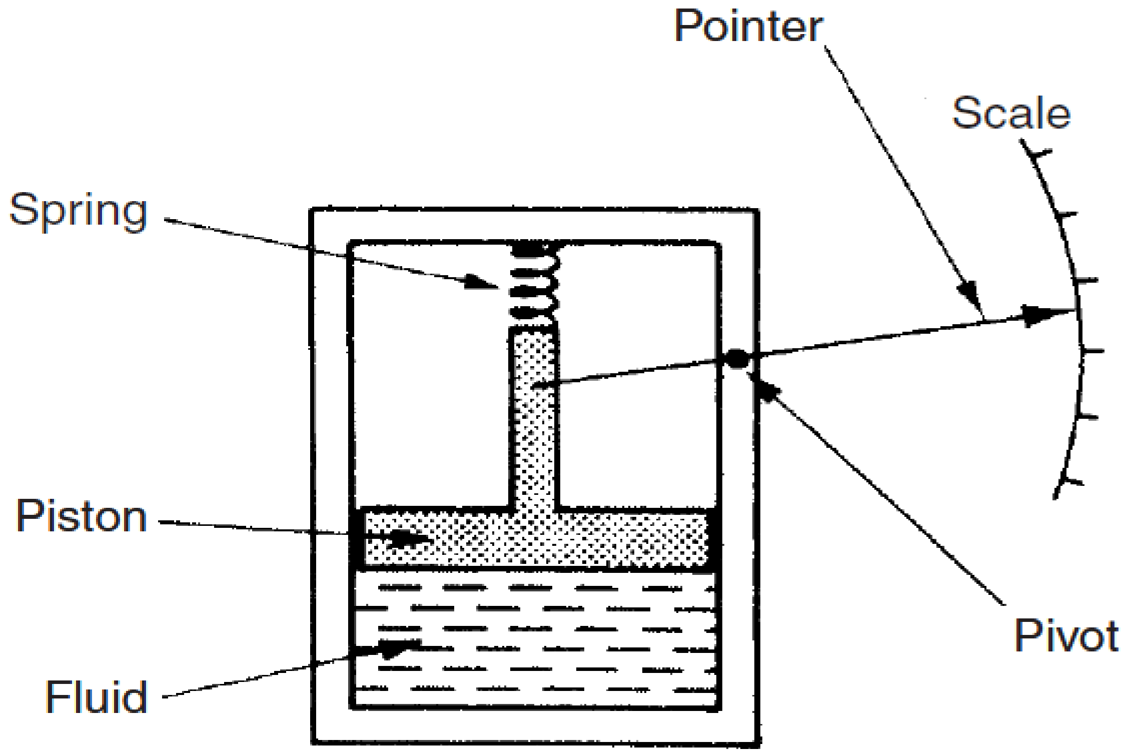
- The 3 basic functions of instrumentation :-
  - Indicating – visualize the process/operation
  - Recording – observe and save the measurement reading
  - Controlling – to control measurement and process such as SCADA in process industry.

1.1 Active and passive instruments

- Instruments are divided into active or passive ones according to whether the instrument output is entirely produced by the quantity being measured or whether the quantity being measured simply modulates the magnitude of some external power source.
- This is illustrated by examples:

Example of a passive instrument

- An example of a passive instrument is the **pressure-measuring** device shown in figure1.1.



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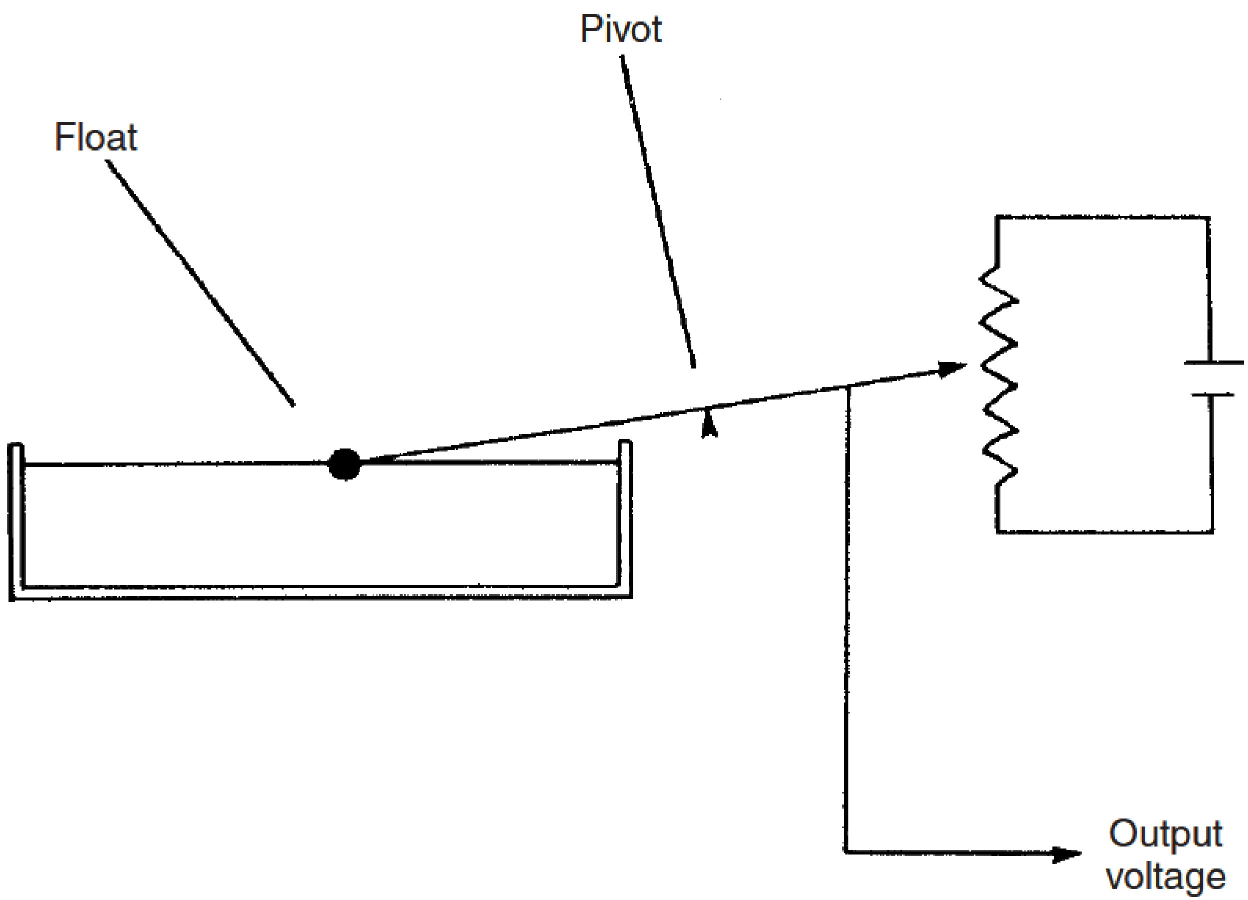
- The pressure of the fluid is translated into a movement of a pointer against a scale.
- The energy expended in moving the pointer is derived entirely from the change in pressure being measured: there are no other energy inputs to the system.

Example of an active instrument

- An example of an active instrument is a float-type petrol tank level indicator as given in figure1.2

Figure1.2 active instrument



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- Here, change in petrol level moves a potentiometer arm, and the output signal is a proportion of external voltage applied across the potentiometer.
- The energy in the output signal comes from the external power source: the primary transducer float system is merely modulating the value of the voltage from this external power source.

Other forms of energy in active instruments

- In active instruments, the external power source is usually in electrical form, but in some cases, it can be other forms of energy such as a pneumatic or hydraulic one.

Comparison between passive and active instrument

- One very important difference between active and passive instruments is the level of measurement resolution that can be obtained.
- With the simple pressure gauge shown, the amount of movement made by the pointer for a particular pressure change is closely defined by the nature of the instrument.

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- Whilst it is possible to increase measurement resolution by making the pointer longer, such that the pointer tip moves through a longer arc, the scope for such improvement is clearly restricted by the practical limit of how long the pointer can conveniently be.
- In an active instrument, however, adjustment of the magnitude of the external energy input allows much greater control over measurement resolution.

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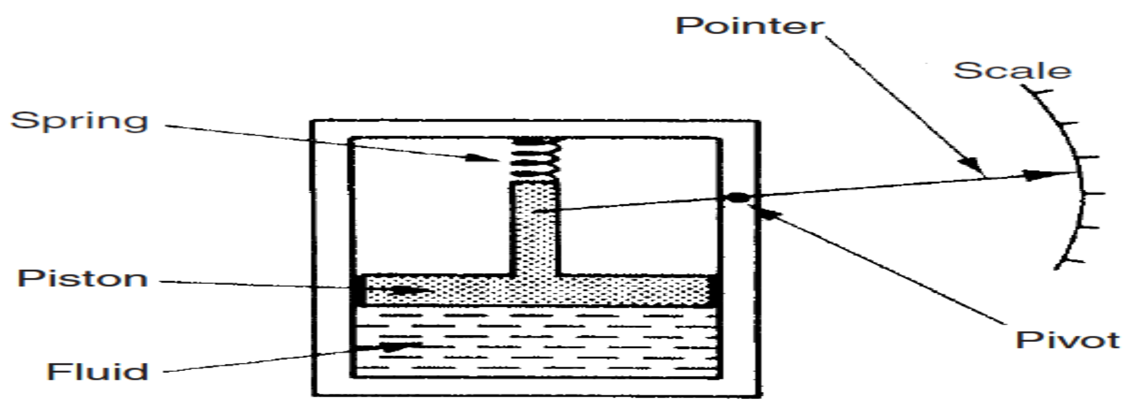
- Whilst the scope for improving measurement resolution is much greater incidentally, it is not infinite because of limitations placed on the magnitude of the external energy input, in consideration of heating effects and for safety reasons.

Cost evaluation

- In terms of cost, passive instruments are normally of a more simple in construction than active ones and are therefore cheaper to manufacture.
- Therefore, choice between active and passive instruments for a particular application involves carefully balancing between the measurement resolution requirements against cost.

Deflection-type instruments

- The pressure gauge just mentioned is a good example of a deflection type instrument, where the value of the quantity being measured is displayed in terms of the amount of movement of a pointer.



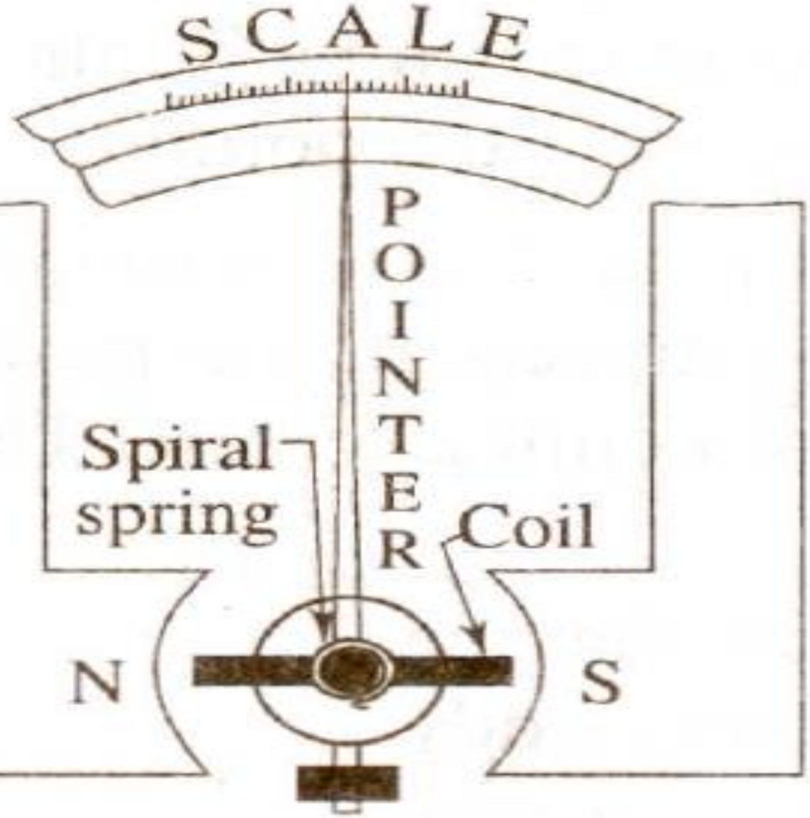
Other deflection instruments

- Other deflection instruments are:

✓ Permanent magnet moving coil meters

✓ Attraction and repulsive Moving iron meter

Permanent magnet moving coil meter



Construction

- Permanent magnet provides a magnetic field. The moving coil is wound on a aluminum frame or is air cored.
- The coil is pivoted in the field of the magnet and is constrained to move in rotary manner.
- Current is led in and out by spiral hair springs which also provide controlling torque.

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- The motion of the current-carrying coil in the magnetic field produces deflecting torque.
- The eddy currents induced in the aluminum former provide damping torque.
- Deflecting torque = kI
- Where k is a constant and I is current through the coil.

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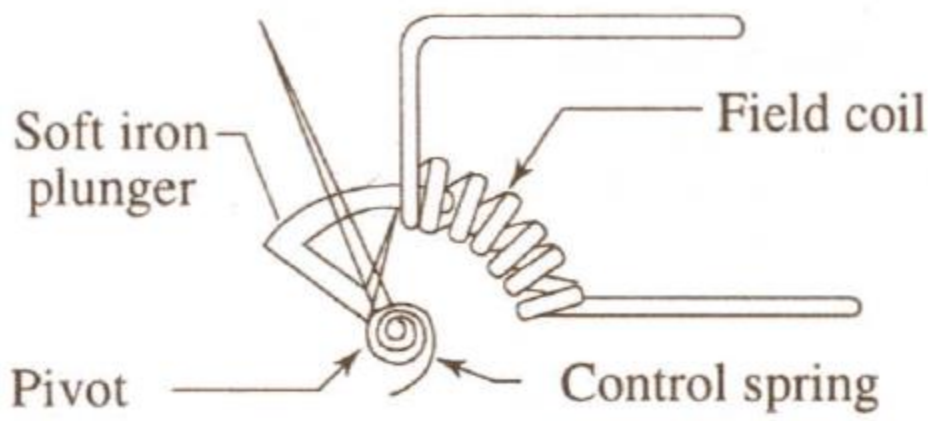
- Controlling torque = $C\theta$
- Where θ is the angular deflection and C is constant.
- For steady deflection,
- Deflecting torque = controlling torque
- $kI = C\theta$
- $\theta = (k/C)I$

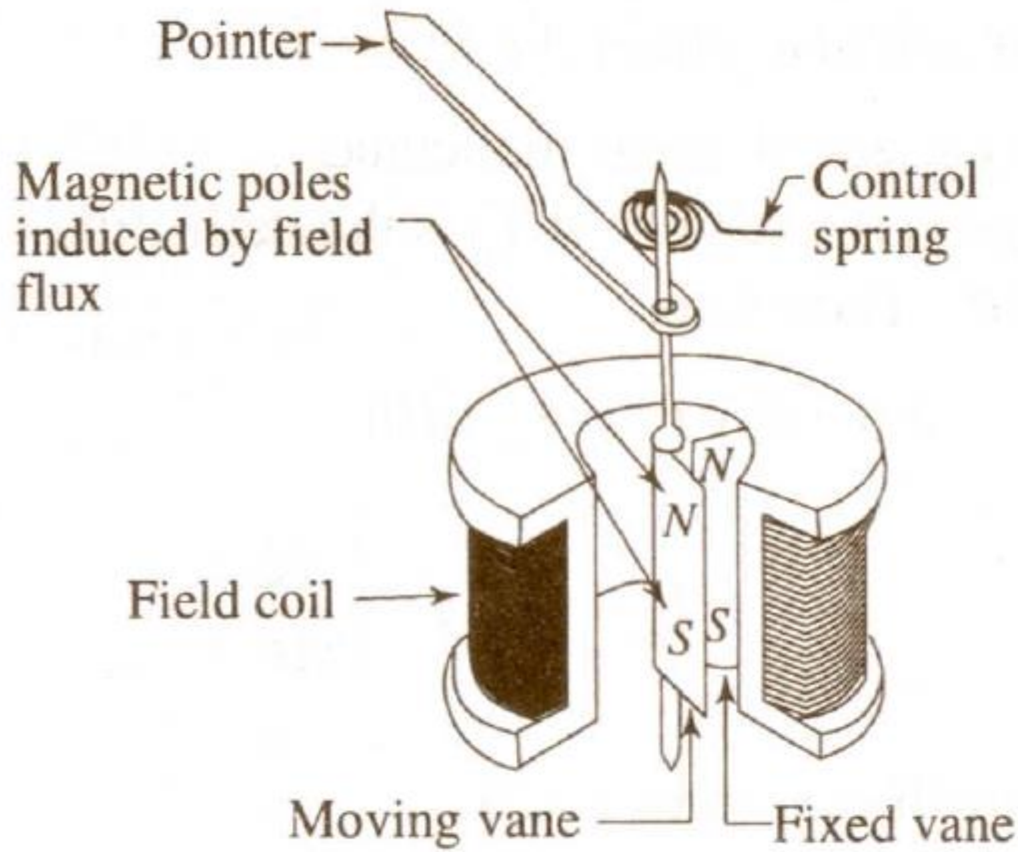
Attraction-type moving iron instrument



Construction and operation

- The current passing through the fixed coil creates magnetic field and the soft iron plunger is attracted into the field of the coil.
- The force on the plunger is always in such a direction as to draw it into the field irrespective of the direction of current in the coil

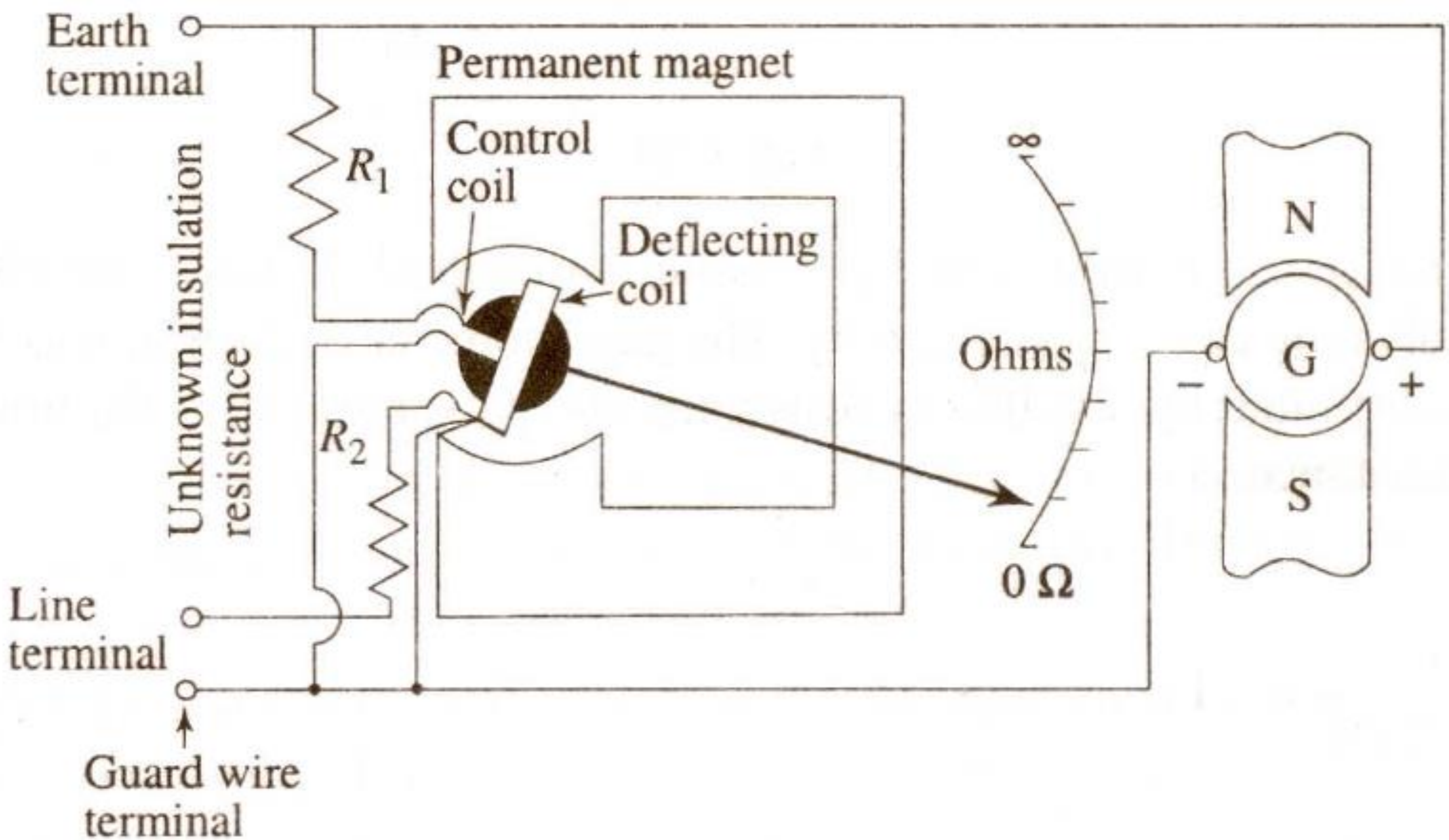
Repulsion-type moving iron instrument



Construction and operation

- The repulsion type instrument shown above has fixed coil and two iron vanes, one fixed and one movable.
- The fixed vane is fixed to the coil frame and the movable vane is attached to the shaft of the instrument.
- When current flows through the coil the two vanes are magnetized in the same direction, resulting in a force of repulsion between them. This force produces a deflecting torque.

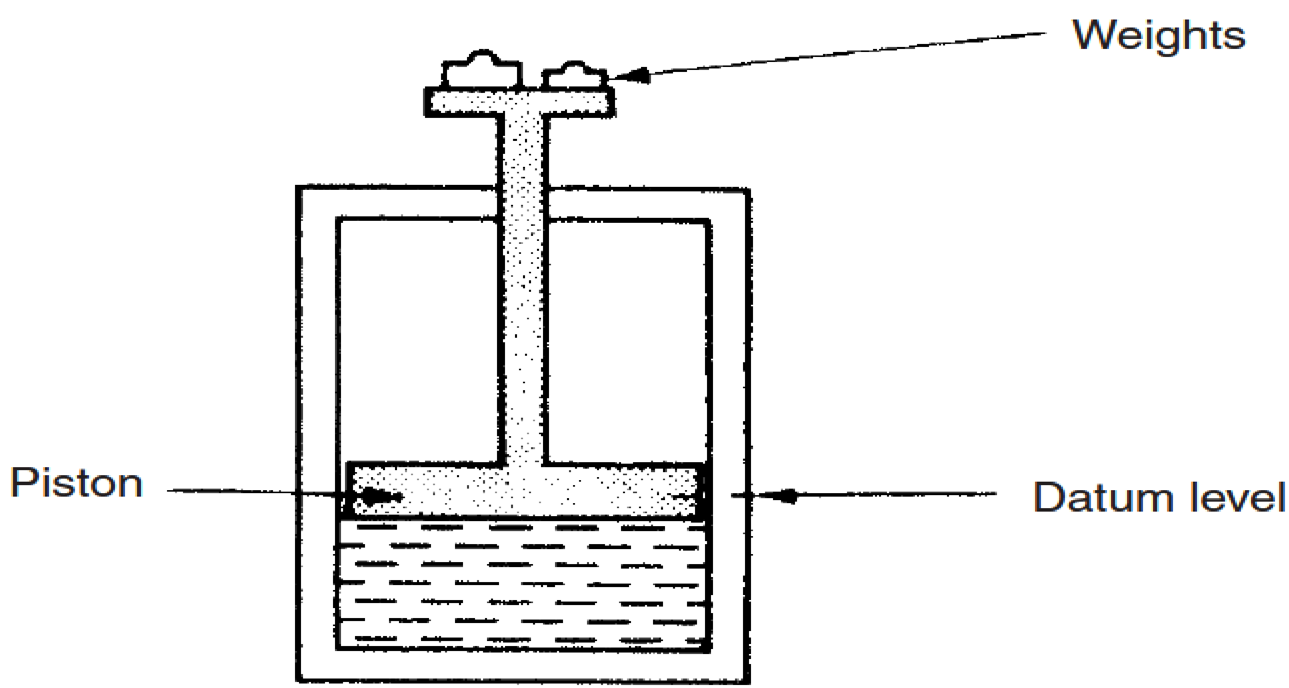
The merger



Earth terminal
Permanent magnet
Control coil
Deflecting coil
R_1
R_2
Unknown insulation resistance
∞
Ohms
0 Ω
N
G
S
−
+
Line terminal
Guard wire terminal

Null-type instrument

- An alternative type of pressure gauge is the deadweight gauge or a null-type instrument shown in Figure 1.3.



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- Here, weights are put on top of the piston until the downward force balances the fluid pressure.
- Weights are added until the piston reaches a datum level, known as the null point.
- Pressure measurement is made in terms of the value of the weights needed to reach this null position.

Accuracy of Null instrument and spring based instrument

- The accuracy of these two instruments depends on different things. For the first one it depends on the linearity and calibration of the spring, whilst for the second it relies on the calibration of the weights.

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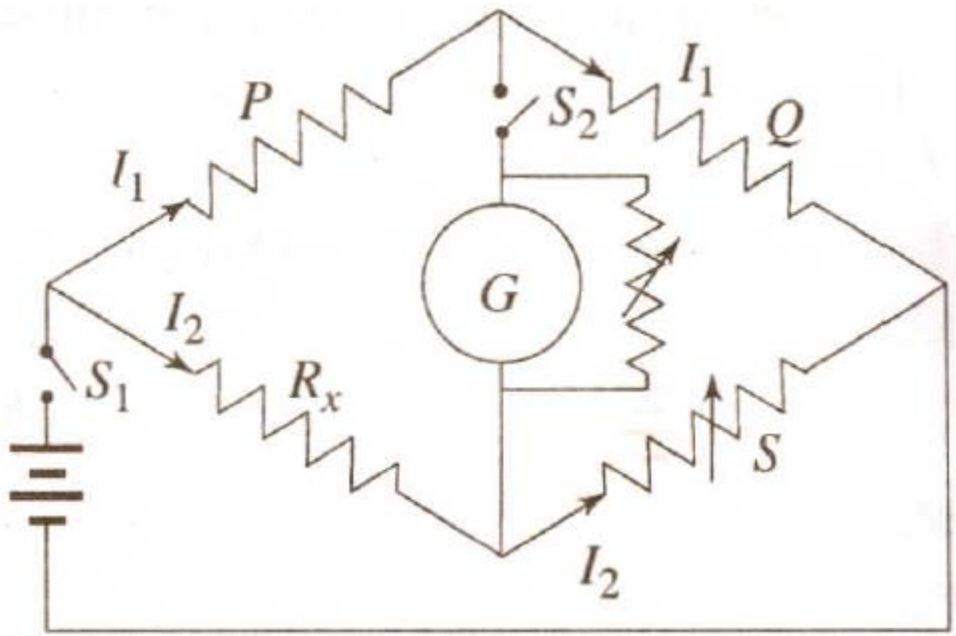
- As calibration of weights is much easier than careful choice and calibration of a linear-characteristic spring, this means that the second type of instrument will normally be the more accurate.
- This is in accordance with the general rule that null-type instruments are more accurate than deflection types.

Electrical Null-type instrument



Wheatstone bridge

Null condition for the Bridge

- Null condition is obtained when the bridge is balanced.
- That is when
- $I_1 P = I_2 R_x$ or $I_1 Q = I_2 S$

Usage convenience

- In terms of usage, the deflection type instrument is clearly more convenient.
- It is far simpler to read the position of a pointer against a scale than to add and subtract weights until a null point is reached.
- A deflection-type instrument is therefore the one that would normally be used in the workplace.

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- However, for calibration duties, the null-type instrument is preferable because of its superior accuracy.
- The extra effort required to use such an instrument is perfectly acceptable in this case because of the infrequent nature of calibration operations.

Analogue instrument

- An analogue instrument gives an output that varies continuously as the quantity being measured changes.
- The output can have an infinite number of values within the range that the instrument is designed to measure.

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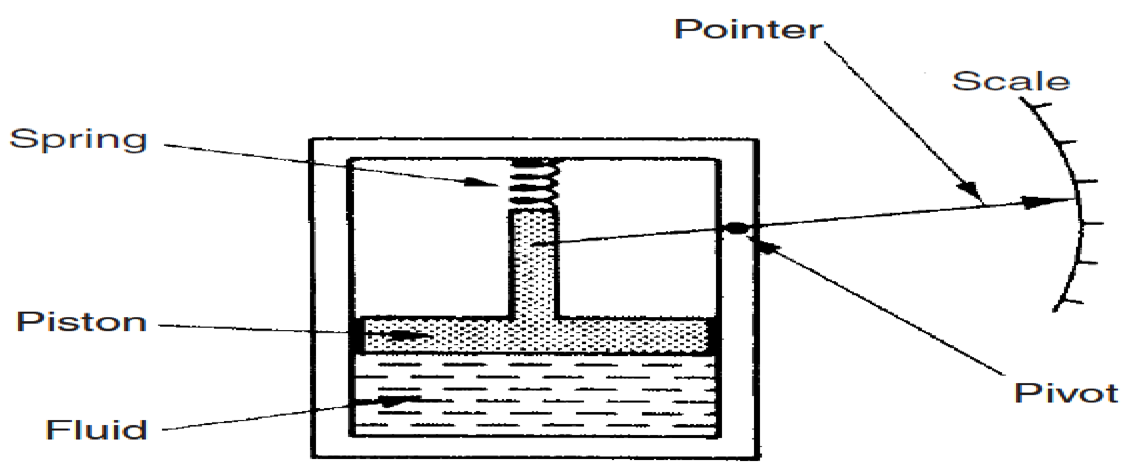
- The deflection-type of pressure gauge described earlier in this chapter (Figure 1.1) is a good example of an analogue instrument.
- As the input value changes, the pointer moves with a smooth continuous motion.



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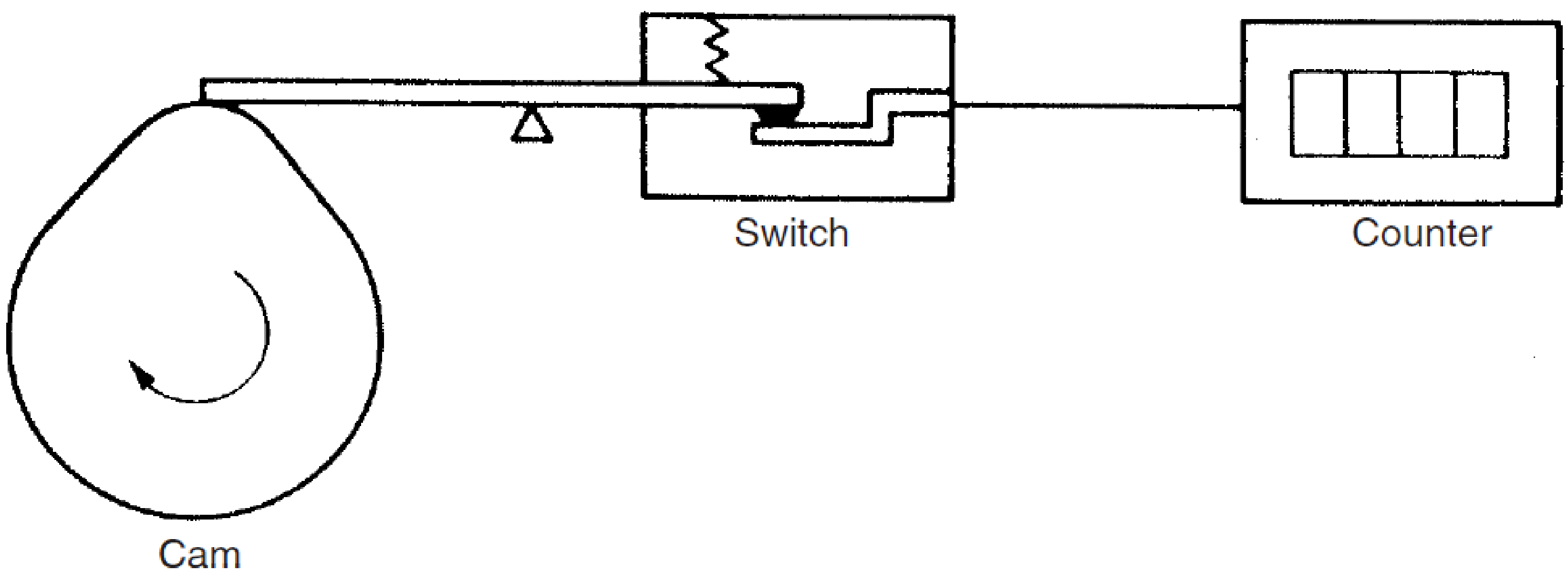
- Whilst the pointer can therefore be in an infinite number of positions within its range of movement, the number of different positions that the eye can discriminate between is strictly limited, this discrimination being dependent upon how large the scale is and how finely it is divided.

Digital instrument

- A digital instrument has an output that varies in discrete steps and so can only have a finite number of values. The rev counter sketched in Figure 1.4 is an example of a digital instrument.

Figure1.4



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- A cam is attached to the revolving body whose motion is being measured, and on each revolution the cam opens and closes a switch. The switching operations are counted by an electronic counter.
- This system can only count whole revolutions and cannot discriminate any motion that is less than a full revolution.

Comparison between analogue and digital instruments

- The distinction between analogue and digital instruments has become particularly important with the rapid growth in the application' of microcomputers to automatic control systems. Any digital computer system, of which the microcomputer is but one example, performs its computations in digital form.
- An instrument whose output is in digital form is therefore particularly advantageous in such applications, as it can be interfaced directly to the control computer.

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- Analogue instruments must be interfaced to the microcomputer by an analogue-to-digital (ADC) converter, which converts the analogue output signal from the instrument into an equivalent digital quantity that can be read into the computer. This conversion has several disadvantages. Firstly, the ADC converter adds a significant cost to the system.

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- Secondly, a finite time is involved in the process of converting an analogue signal to a digital quantity, and this time can be critical in the control of fast processes where the accuracy of control depends on the speed of the controlling computer.
- Degrading the speed of operation of the control computer by imposing a requirement for ADC conversion thus impairs the accuracy by which the process is controlled.

Indicating instruments and instruments with a signal output

- The final way in which instruments can be divided is between those that merely give an audio or visual indication of the magnitude of the physical quantity measured and those that give an output in the form of a measurement signal whose magnitude is proportional to the measured quantity.

Indicating instruments

- The class of indicating instruments normally includes all null-type instruments and most passive ones.
- Indicators can also be further divided into those that have an analogue output and those that have a digital display.
- A common analogue indicator is the liquid-in-glass thermometer.

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- The older mechanical form of this is an analogue type of instrument that gives an output consisting of a rotating pointer moving against a scale (or sometimes a rotating scale moving against a pointer).

major drawback

- One major drawback with indicating devices is that human intervention is required to read and record a measurement.
- This process is particularly prone to error in the case of analogue output displays, although digital displays are not very prone to error unless the human reader is careless.

Smart instruments

- The advent of the microprocessor has created a new division in instruments between those that do incorporate a microprocessor (smart) and those that don't.
- Smart devices are considered in detail in later

Self assessment questions

2.1 Explain what is meant by:
   (a) active instruments
   (b) passive instruments.
   Give examples of each and discuss the relative merits of these two classes of instruments.

2.2 Discuss the advantages and disadvantages of null and deflection types of measuring instrument. What are null types of instrument mainly used for and why?

End

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