TVET CERTIFICATE IV in INDUSTRIAL ELECTRICITY

ELECTRICAL MEASUREMENTS AND INSTRUMENTATION

IELEI401

Perform electrical measurements and instrumentation

Competence

Learning hours: 50

Credits: 5

Sector: Energy

Sub-sector: All

Module Note Issue date: June, 2020

Purpose Statement

This core module describes the skills, knowledge and attitude required to perform electrical measurement and instrumentation. The learner will be able to identify tools and measurement instruments, arrange materials and tools in the working area. He/she will be also able to describe different methods of measurement, handle measuring equipment and devices, identify errors in measurement and be able to differentiate analogue and digital measuring instruments

Elements of competence and performance criteria		Page No.
Learning Unit	**Performance Criteria**	
1. Prepare preliminary activities	1.1 Proper interpretation of electrical drawings	3
	1.2 Appropriate identification of tools and measurement instruments	
	1.3 Proper arrangement of materials and tools into the working area	
	1.4 Proper identification of PPE (Personal Protective Equipment)	
	1.5 Proper identification of electrical Energy system: AC or DC	
2. Carry out measurement and instrumentation	1.1 Proper description of different methods of measurement.	48
	1.2 Proper handling of measuring equipment and devices.	
	1.3 Proper execution of measurements	
3. Cleaning of workplace	1.1 Proper cleaning tools and equipment	67
	1.2 Proper Cleaning of the working area	
	1.3 Proper management of waste materials	

Total number of pages: 94

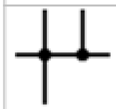
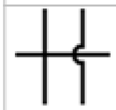
Learning Unit 1. Prepare preliminary activities

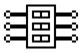
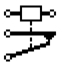
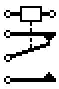
Learning Outcome 1.1: Interpret electrical drawings

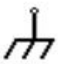
Content/Topic 1. Electrical symbols

Drawing electrical circuit diagrams, you will need to represent various electrical and electronic devices (such as batteries, wires, resistors, and transistors) as pictograms called electrical symbols.

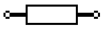
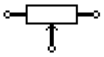
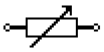
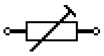
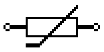
Traditionally these symbols may vary from country to country, but today they are standardized internationally to a large extent.

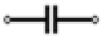
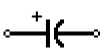
Symbol	Component name	Meaning
Wire Symbols		
	Electrical Wire	Conductor of electrical current
	Connected Wires	Connected crossing
	Not Connected Wires	Wires are not connected
Switch Symbols and Relay Symbols		
	SPST Toggle Switch	Disconnects current when open
	SPDT Toggle Switch	Selects between two connections
	Pushbutton Switch (N.O)	Momentary switch - normally open

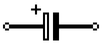
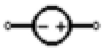
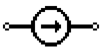
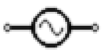
	Pushbutton Switch (N.C)	Momentary switch - normally closed
	DIP Switch	DIP switch is used for onboard configuration
	SPST Relay	Relay open / close connection by an electromagnet
	SPDT Relay	
	Jumper	Close connection by jumper insertion on pins.
	Solder Bridge	Solder to close connection

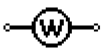
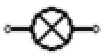
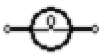
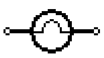
Ground Symbols		
	Earth Ground	Used for zero potential reference and electrical shock protection.
	Chassis Ground	Connected to the chassis of the circuit
	Digital / Common Ground	

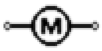
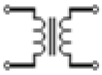
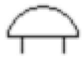
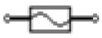
Resistor Symbols		
	Resistor (IEEE)	Resistor reduces the current flow.

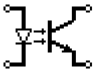
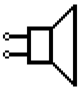
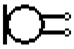
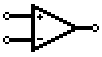
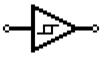
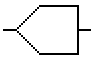
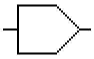
	Resistor (IEC)	
	Potentiometer (IEEE)	Adjustable resistor - has 3 terminals.
	Potentiometer (IEC)	
	Variable Resistor / Rheostat(IEEE)	Adjustable resistor - has 2 terminals.
	Variable Resistor / Rheostat(IEC)	
	Trimmer Resistor	Preset resistor
	Thermistor	Thermal resistor - change resistance when temperature changes

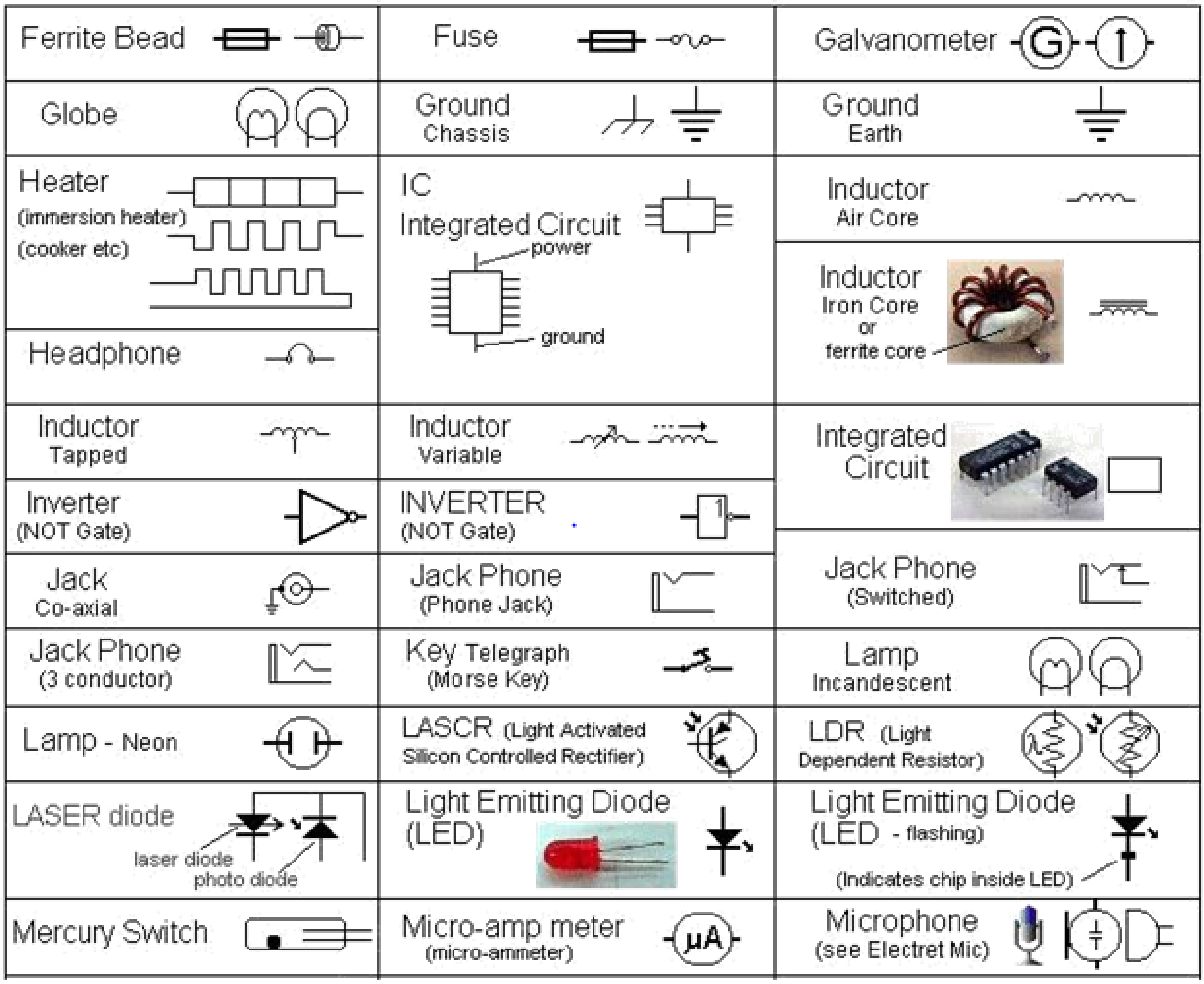
Capacitor Symbols		
	Capacitor	Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC.
	Capacitor	
	Polarized Capacitor	Electrolytic capacitor

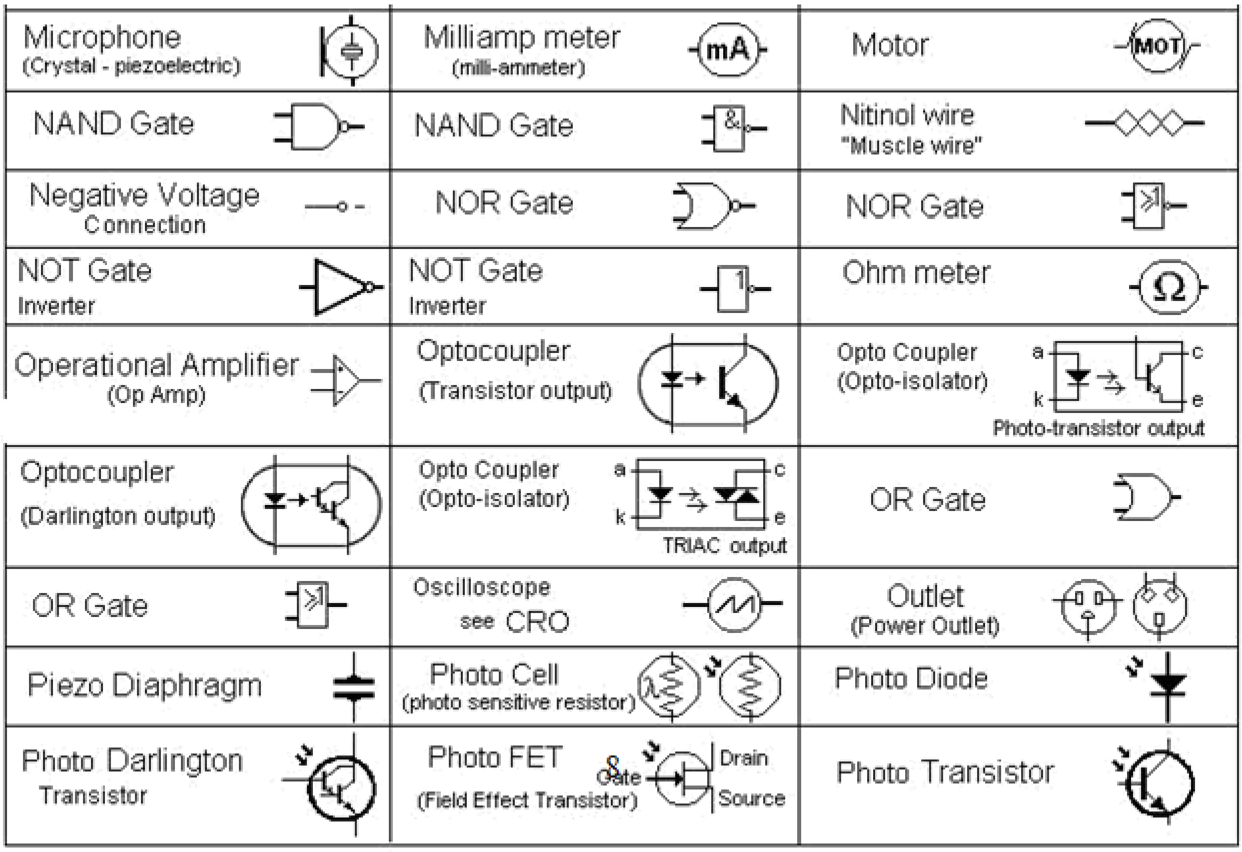
	Polarized Capacitor	Electrolytic capacitor
	Variable Capacitor	Adjustable capacitance
Inductor / Coil Symbols		
	Inductor	Coil / solenoid that generates magnetic field
	Iron Core Inductor	Includes iron
	Variable Inductor	
Power Supply Symbols		
	Voltage Source	Generates voltage
	Current Source	Generates current.
	AC Voltage Source	AC (alternate) voltage source
	Generator	Electrical voltage is generated by mechanical rotation of the generator
	Battery Cell	Generates constant voltage

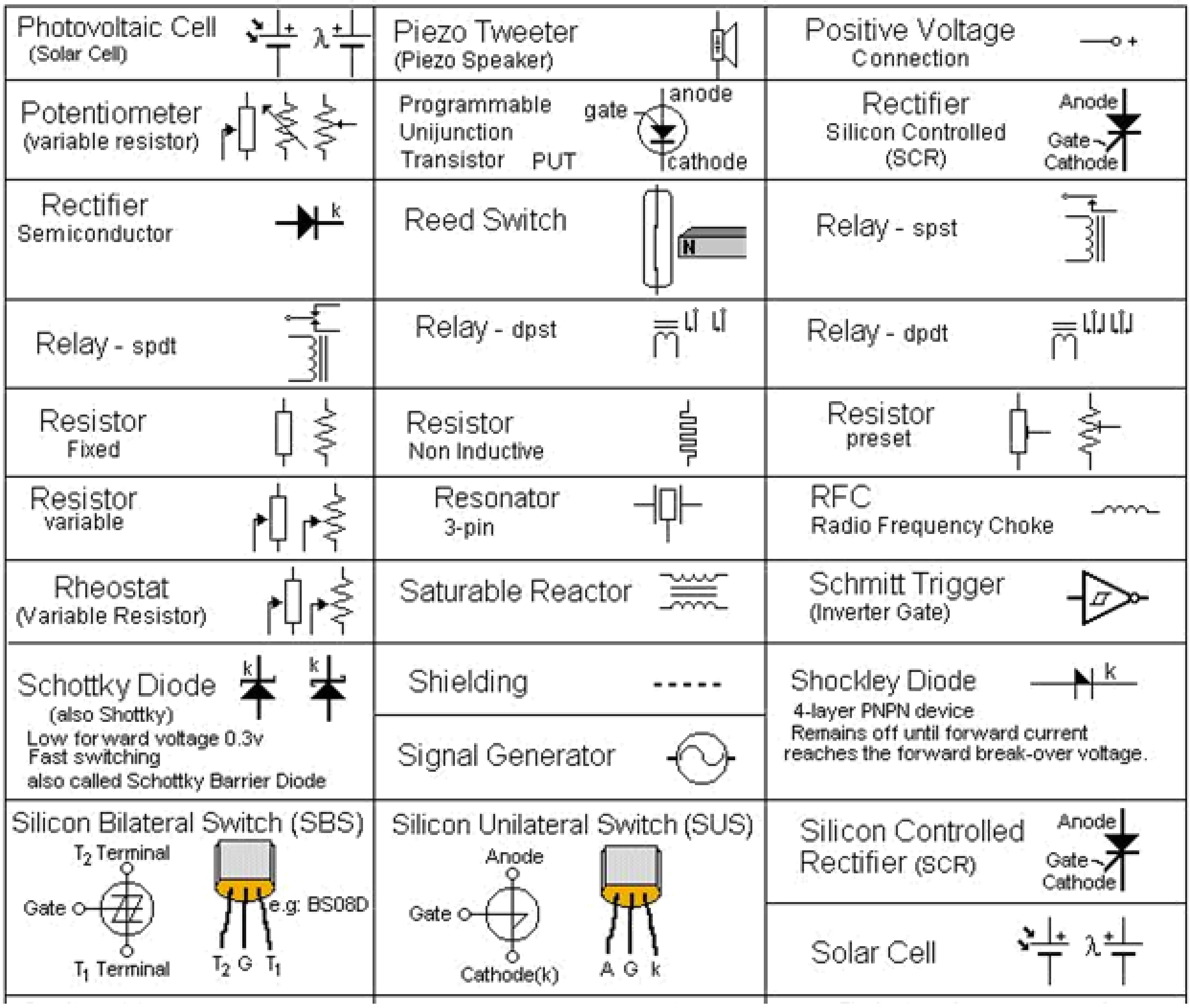
	Battery	Generates constant voltage
	Controlled Voltage Source	Generates voltage as a function of voltage or current of other circuit element.
	Controlled Current Source	Generates current as a function of voltage or current of other circuit element.
Meter Symbols		
	Voltmeter	Measures voltage. Has very high resistance. Connected in parallel.
	Ammeter	Measures electric current. Has near zero resistance. Connected serially.
	Ohmmeter	Measures resistance
	Wattmeter	Measures electric power
Lamp / Light Bulb Symbols		
	Lamp / light bulb	Generates light when current flows through
	Lamp / light bulb	
	Lamp / light bulb	

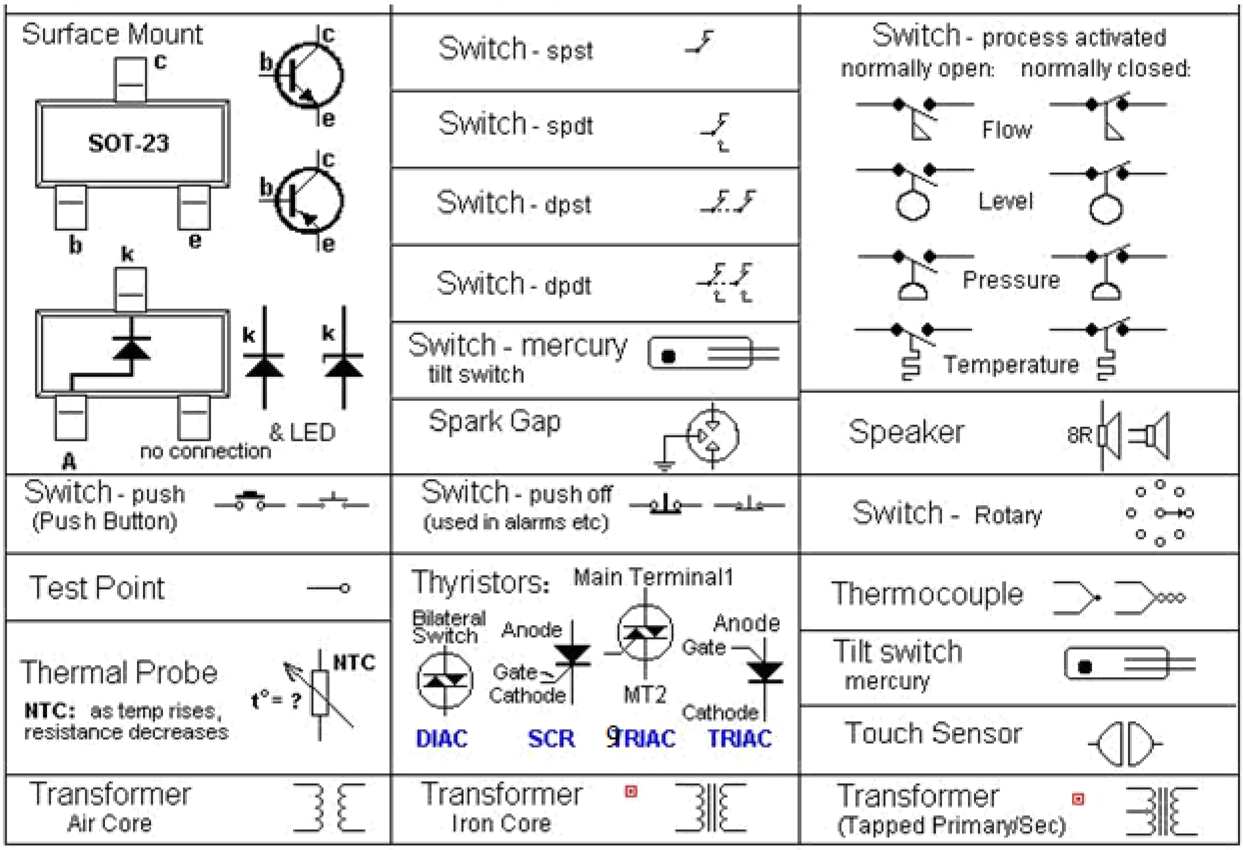
Misc. Symbols		
	Motor	Electric motor
	Transformer	Change AC voltage from high to low or low to high.
	Electric bell	Rings when activated
	Buzzer	Produce buzzing sound
	Fuse	The fuse disconnects when current above threshold. Used to protect circuit from high currents.
	Fuse	
	Bus	Contains several wires. Usually for data / address.
	Bus	
	Bus	

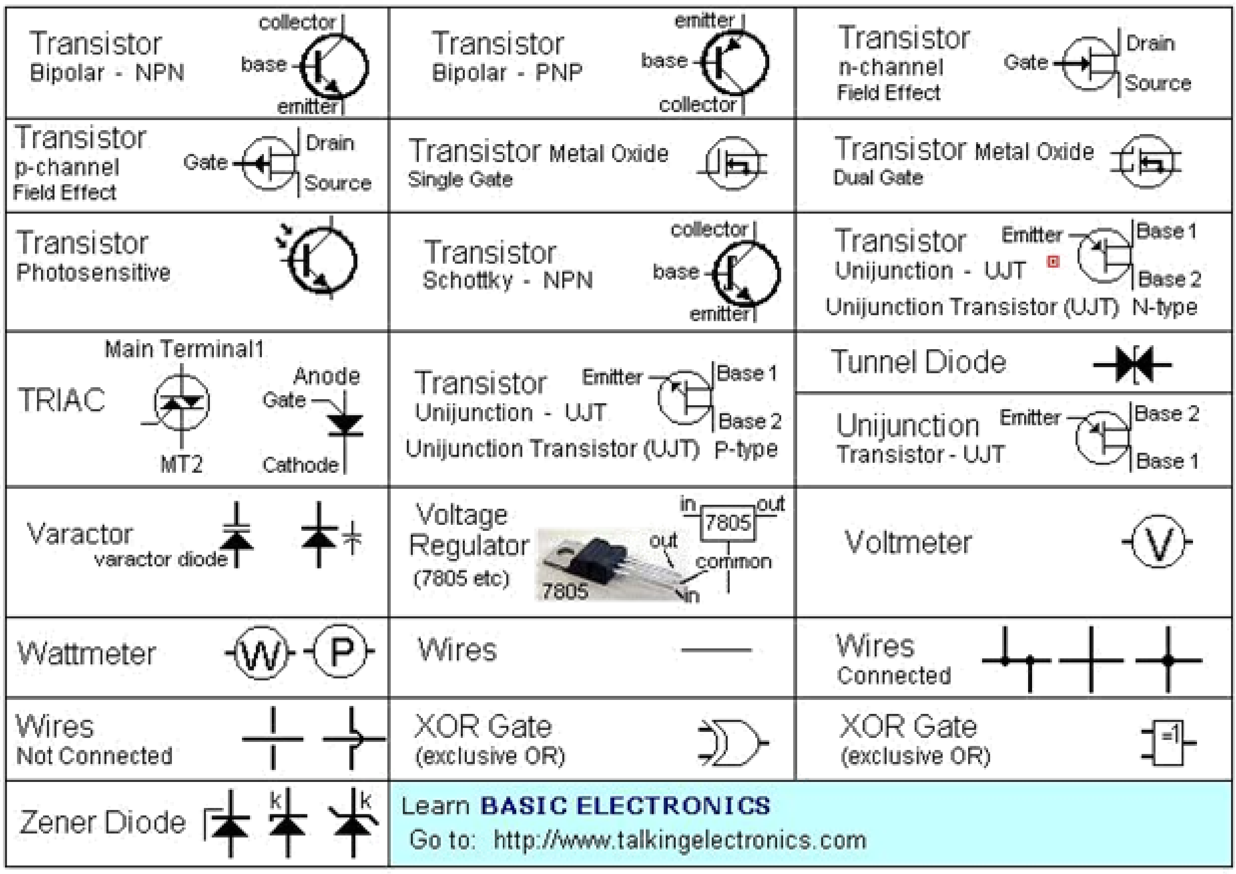
	Opto coupler / Opto-isolator	Opto coupler isolates connection to other board
	Loudspeaker	Converts electrical signal to sound waves
	Microphone	Converts sound waves to electrical signal
	Operational Amplifier	Amplify input signal
	Schmitt Trigger	Operates with hysteresis to reduce noise.
	Analog-to-digital converter (ADC)	Converts analog signal to digital numbers
	Digital-to-Analog converter (DAC)	Converts digital numbers to analog signal


Ferrite Bead
Fuse
Galvanometer
Globe
Ground Chassis
Ground Earth
Heater (immersion heater) (cooker etc)
IC Integrated Circuit
power
ground
Inductor Air Core
Inductor Iron Core or ferrite core
Headphone
Inductor Tapped
Inductor Variable
Integrated Circuit
Inverter (NOT Gate)
INVERTER (NOT Gate)
Jack Co-axial
Jack Phone (Phone Jack)
Jack Phone (Switched)
Jack Phone (3 conductor)
Key Telegraph (Morse Key)
Lamp Incandescent
Lamp - Neon
LASCR (Light Activated Silicon Controlled Rectifier)
LDR (Light Dependent Resistor)
LASER diode
laser diode
photo diode
Light Emitting Diode (LED)
Light Emitting Diode (LED - flashing)
(Indicates chip inside LED)
Mercury Switch
Micro-amp meter (micro-ammeter)
μA
Microphone (see Electret Mic)


Microphone (Crystal - piezoelectric)
Milliamp meter (milli-ammeter)
mA
Motor
MOT
NAND Gate
NAND Gate
&
Nitinol wire "Muscle wire"
Negative Voltage Connection
NOR Gate
NOR Gate
NOT Gate Inverter
NOT Gate Inverter
Ohm meter
Ω
Operational Amplifier (Op Amp)
Optocoupler (Transistor output)
Opto Coupler (Opto-isolator)
a
c
k
e
Photo-transistor output
Optocoupler (Darlington output)
Opto Coupler (Opto-isolator)
TRIAC output
OR Gate
OR Gate
Oscilloscope see CRO
Outlet (Power Outlet)
Piezo Diaphragm
Photo Cell (photo sensitive resistor)
Photo Diode
Photo Darlington Transistor
Photo FET (Field Effect Transistor)
Gate
Drain
Source
Photo Transistor


Photovoltaic Cell
(Solar Cell)
Piezo Tweeter
(Piezo Speaker)
Positive Voltage
Connection
Potentiometer
(variable resistor)
Programmable
Unijunction
Transistor PUT
gate
anode
cathode
Rectifier
Silicon Controlled
(SCR)
Anode
Gate
Cathode
Rectifier
Semiconductor
k
Reed Switch
N
Relay - spst
Relay - spdt
Relay - dpst
Relay - dpdt
Resistor
Fixed
Resistor
Non Inductive
Resistor
preset
Resistor
variable
Resonator
3-pin
RFC
Radio Frequency Choke
Rheostat
(Variable Resistor)
Saturable Reactor
Schmitt Trigger
(Inverter Gate)
Schottky Diode
(also Shottky)
Low forward voltage 0.3v
Fast switching
also called Schottky Barrier Diode
k
k
Shielding
Signal Generator
Shockley Diode
k
4-layer PNPN device
Remains off until forward current
reaches the forward break-over voltage.
Silicon Bilateral Switch (SBS)
T2 Terminal
Gate
T1 Terminal
e.g: BS08D
T2 G T1
Silicon Unilateral Switch (SUS)
Anode
Gate
Cathode(k)
A G k
Silicon Controlled
Rectifier (SCR)
Anode
Gate
Cathode
Solar Cell


Surface Mount
c
SOT-23
b
e
b
c
e
k
A
no connection
& LED
k
Switch - spst
Switch - spdt
Switch - dpst
Switch - dpdt
Switch - mercury
tilt switch
Spark Gap
Switch - process activated
normally open:
normally closed:
Flow
Level
Pressure
Temperature
Speaker
8R
Switch - push
(Push Button)
Switch - push off
(used in alarms etc)
Switch - Rotary
Test Point
Thyristors:
Main Terminal1
Bilateral Switch
Anode
Gate
Cathode
MT2
DIAC
SCR
TRIAC
TRIAC
Thermocouple
Tilt switch
mercury
Touch Sensor
Thermal Probe
NTC
t° = ?
NTC: as temp rises, resistance decreases
Transformer
Air Core
Transformer
Iron Core
Transformer
(Tapped Primary/Sec)


Transistor
Bipolar - NPN
collector
base
emitter
Transistor
Bipolar - PNP
emitter
base
collector
Transistor
n-channel
Field Effect
Gate
Drain
Source
Transistor
p-channel
Field Effect
Gate
Drain
Source
Transistor Metal Oxide
Single Gate
Transistor Metal Oxide
Dual Gate
Transistor
Photosensitive
Transistor
Schottky - NPN
collector
base
emitter
Transistor
Unijunction - UJT
Emitter
Base 1
Base 2
Unijunction Transistor (UJT) N-type
TRIAC
Main Terminal1
Anode
Gate
MT2
Cathode
Transistor
Unijunction - UJT
Emitter
Base 1
Base 2
Unijunction Transistor (UJT) P-type
Tunnel Diode
Unijunction
Transistor - UJT
Emitter
Base 2
Base 1
Varactor
varactor diode
Voltage
Regulator
(7805 etc)
in
out
7805
common
Voltmeter
Wattmeter
Wires
Wires
Connected
Wires
Not Connected
XOR Gate
(exclusive OR)
XOR Gate
(exclusive OR)
=1
Zener Diode
k
k
Learn BASIC ELECTRONICS
Go to: http://www.talkingelectronics.com

Content/Topic 2. Types of electrical drawing

Electrical drawings plays an important role in electrical installation works that they convey information about connection of various devices and equipment with mains. The information on drawings provides the complete design or plan of electrical installation and also helps to assemble the various equipment.

Some of the electrical wiring diagrams are discussed below. Before knowing about these diagrams, first one must aware and have idea about various symbols used while preparing drawing and also for understanding the wiring connections. Check out various electrical wiring symbols.

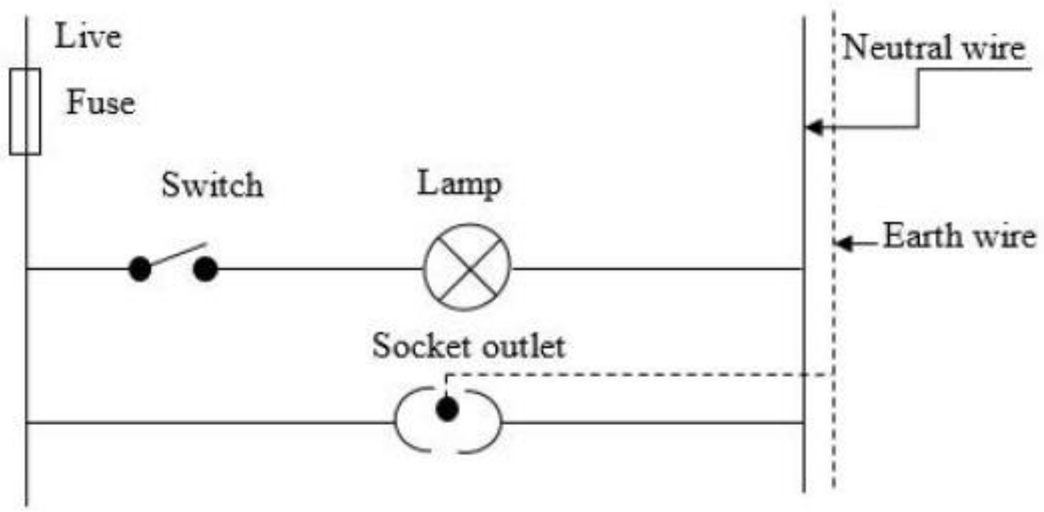
1. Block Diagram

It is a functional drawing which shows and describes the main operating principles of the equipment or devices. It consists of principle functions or parts represented by blocks and are connected through lines that show the relationship between the blocks.

This diagram is usually drawn before implementing a circuit diagram. It will not give any detailed information about the system and also leaves the information about smaller components. And hence, most technicians have limited interest about this diagram.

2. Circuit Drawing (Diagram)

In this, electrical circuit is graphically represented in a simplified manner. It includes the position information (in cm or m or mm) of various elements like light fixtures, receptacle boxes, junction boxes, ceiling fans, etc.



3. Line Diagram

It is a simplified notation of an electrical system, also called as one-line diagram or single line diagram. It is similar to the block diagram except that various electrical elements such as transformers, switches, lights, fans, circuit breakers, and motors are represented by standard schematic symbols.

It consists of symbols to represent the components and lines to represent the wires or conductors which connect the components together.

The line diagram is actually derived from the block diagram. It doesn‘t give any layout of the parts and their detail wiring information of the components.

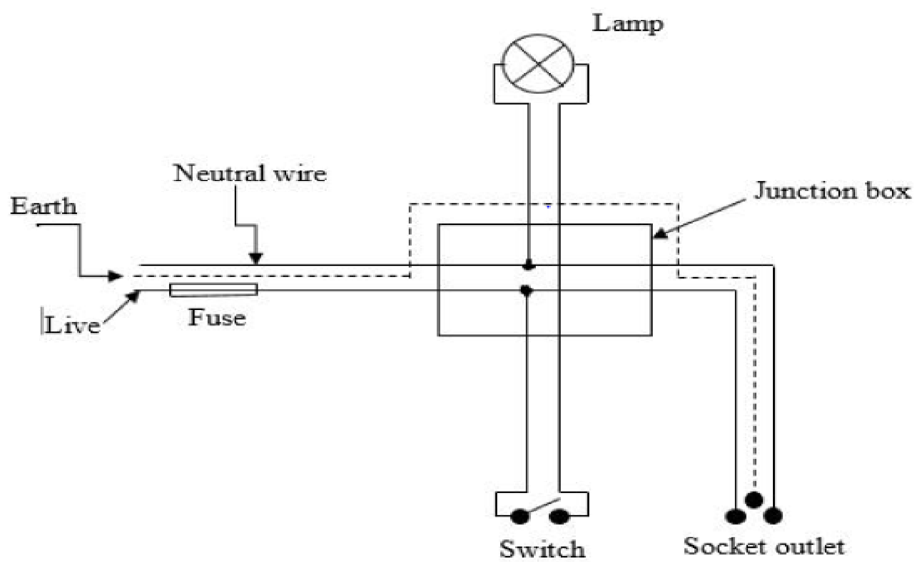
However, one can do wiring by following the information given in this diagram. These diagrams are usually intended to illustrate the working of an electric circuit.

4. Wiring Diagram

The electrical wiring diagram is a pictorial representation of the circuit which shows the wiring between the parts or elements or equipment.

It gives detailed information about wiring such that one can get an idea of making connection between the devices. It includes relative position, arrangement of the devices and also terminals on the devices.

It shows power supplies and earth connections, control and signal functions (with simplified shapes), termination of unused contacts and leads, interconnection via plugs, blocks, sockets, terminal posts, lead-through, etc.



5. Wiring Preparation

As we are discussing the sequence of steps in wiring like understanding the safety, knowing types of wiring systems, understanding the difference among various electrical drawings and symbols, the next step of electrical wiring process is the preparation of wires or cables and electrical tools.

The wiring preparation includes the following considerations.

1. The type of conductor can be single solid wire or stranded wire conductor (which is made up of a number of thin stands). Single solid wires are not flexible and are used where rigid connections are required such as power switching contractors. Mostly stranded conductors are preferred for electrical installations.

2. The specifications of the wire depend on the several factors like number of strands in the conductor, insulation type, cross section area of the wire, diameter of the strands, etc.

3. Choose the wires depends on the color code mentioned by various standards such as red for phase wire, black for neutral, green for earth and so on. Click here to know briefly about the electrical wiring colors of the wires or cables.

4. Various basic electrical tools are required to do the installation work and some of these tools include cutter, strippers, testers, pliers, etc. These tools are explained in our earlier article so please check those electrical tools by clicking here.

5. Choose the components such as electrical boxes, switches, receptacles, etc. based on their size and rating.

Start wiring the components together by following the wiring diagrams once components, tools and cables are selected, followed by considering the safety to personnel as well as equipment.

Content/Topic 3. Interpretation of different electrical drawings and schematic diagrams

We know that electrical circuit is a closed path through which electricity flows from phase or hot wire to the device or apparatus and then back the source though neutral wire.

Along the way, the electricity path may consist of fixtures, switches, receptacles, junction boxes, etc. So the wiring may be routed through these elements before actually making connections with apparatus or device.

Majorly, the wiring is divided into two types, namely parallel wiring and series wiring depending on the way the devices are powered or connected to the supply.

In parallel wiring, several devices on the installation are powered on a single circuit. It is the most accepted wiring in homes and industries, in which devices are connected in parallel with the supply source as shown in figure.

In this, both phase (or hot) and neutral cables are routed through the electrical boxes (junction boxes) from which individual receptacles, fixtures, and devices are branched.

1. Parallel wiring

The series wiring is the rarely used wiring in which hot wire is routed through the several devices and then last device terminal is connected to the neutral (or negative) wire. It is like an old Christmas lights or serial lights wiring in which one light burnout leads to the shutdown of the entire network.

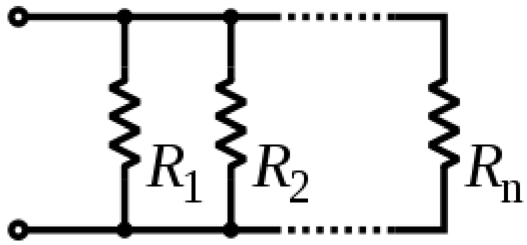


Fig. Parallel circuit

2. Series wiring

For a better understanding of the wiring concept, here we are giving some examples of the wiring circuits which we are dealing daily in our homes.

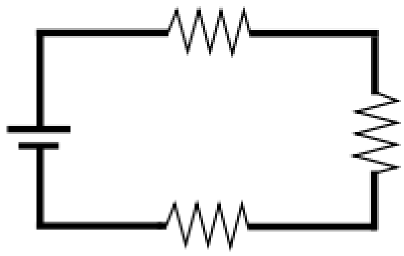


Fig. Series circuit

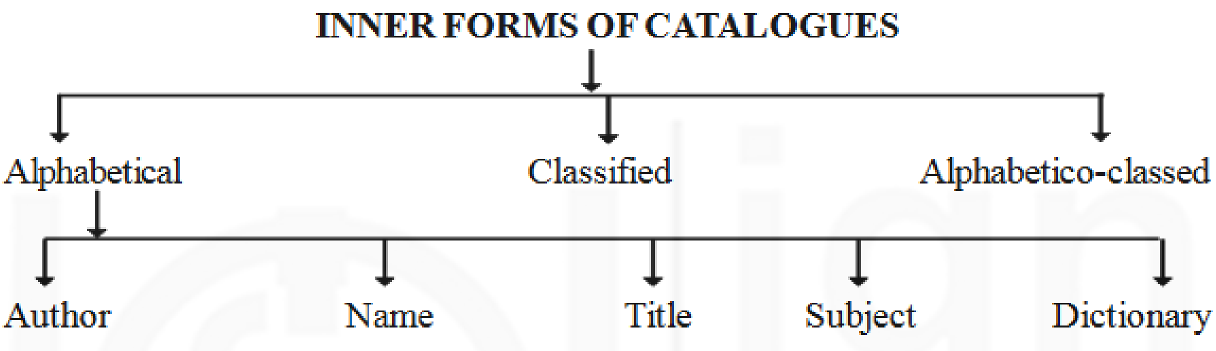
Content/Topic 3. Interpretation of the catalogue information

CATALOGUE

A library catalogue has a long history of one and a half century. It has evolved over the period of time. The evolution has taken place in the form, format as well as contents of a catalogue. Developments in document production and changing user needs have affected the library catalogue. Information Communication Technology (ICT) has also played a role in the developments in catalogues and cataloguing. A catalogue is discussed from the point of view of its external form/ physical appearance and internal form. The different forms have been discussed with their relative advantages and disadvantages in this Unit.

- **Inner forms of a catalogue**

The inner form of a library catalogue refers to the arrangement of a catalogue entry in a logical and systematic order to fall into a helpful sequence for storage and retrieval. The chart below depicts the various inner forms of a catalogue.



There are three types of inner forms of a catalogue, viz. alphabetical, classified and alphabetico-classed. Author, Name, Title, Subject and Dictionary catalogue fall in the category of an alphabetical catalogue. A Classified Catalogue is so named because it is arranged in a classified order. Classified order is an artificial order which may be difficult to use. Hence a classified catalogue has two parts the other part being alphabetical which is easy to use and leads the user to the classified part. Alphabetico-classed catalogue is a variation of the classified catalogue. It overcomes the shortcoming of the artificiality of a classified arrangement by making it classified alphabetically.

1. Author Catalogue

Author is the person who is chiefly responsible for the intellectual thought content of a work. In simple words, author is the creator of a work. In an author catalogue, the entries of documents are under author's name and arranged alphabetically. It provides access to documents by the names of their authors. In other words, the leading section of an author catalogue would comprise the name of an author. An author is generally a person or a corporate body who is responsible for the thought contents of the document brought out under the name. Listing of personal names of author varies greatly because of the cultural traditions in the naming of person in different regions of the world. For example, names of persons in Western countries, Indic names, Muslim names, Chinese and Japanese names differ as per their own traditions. Which part of the names should be taken as the lead in a catalogue has been set by cataloguing codes and there are established practices. There are also a variety of corporate bodies under whose names documents are published. Although we are not concerned very much with rendering of names in catalogue entries here, it is important to note that their filing position is determined by the rendering of names. Inaccuracies in the rendering of names would seriously affect the alphabetical arrangement of entries in the catalogue. The catalogues of the British Library, the Library of Congress, the National Library of India are some of the fine examples of author catalogues.

Libraries may have author catalogues arranged in three different ways:

a) There may be an exclusive author catalogue without entries mixing it with any other entries such as titles, subjects, series, etc.
b) Author entries may form part and parcel of a dictionary catalogue.
c) Author entries may form part of the alphabetical index of a classified catalogue.

Irrespective of the form in which an author catalogue exists, it provides an important approach to a document. If the user approaches the catalogue with the correct name of an author, the catalogue immediately gives the person all the documents by the author. To help a user, the other variants of the name of an author are usually provided as cross-references in a catalogue.

Advantages

1)It brings together the titles of books of the same author at one place in the catalogue
2)It helps a user to obtain at a glance what books are available in the library by a given author. This function, can however be fulfilled by author entries in other inner forms of a library catalogue. In a classified catalogue, this function is performed by the alphabetical index of dictionary part.
3) It ensures that there will be no scattering of works of the same author through the catalogue.

Disadvantages

1) Approaches of readers under subject, collaborators, distinctive titles etc. cannot be satisfied. However it requires that the reader must know the exact name of the author and title. In case the author is known by different forms of name or pseudonym, the reader may be helped with the use of see references.

2. Name Catalogue

A name catalogue is a variation and extension of an author catalogue. It contains entries for works of one author and also for books written on him. All entries are arranged alphabetically by the name of the author. In other words, a name catalogue is a compound or mixed type of catalogue which combines the author and subject entries (the subject entries representing the author as a subject) into one alphabetical sequence. In this type of catalogue autobiography, biography and other critical studies, memoirs and diary of an author, are arranged along with his original work. The author entries include:

- corporate authors, both as an author as well as a subject
- name series
- place name forming part of an author heading

3. Title Catalogue

In a title catalogue, the titles of documents occupy the leading section of entries, which are arranged in an alphabetical order. Queries of readers who remember only the exact title can be answered with the help of a title catalogue. However, it is noticed that many of the readers do not spell out a title exactly the way it appears on the title page, particularly non-fiction titles. To fulfill title approach of readers, entries can be selectively provided in catalogues of public libraries for fiction and for those that are well-known by their titles. It is a part of dictionary catalogue or part of author-title index of classified catalogue.

Advantages

1) Satisfies the approaches of readers especially in cases for classical languages and for fiction, drama, poetry and for the class literature.

Disadvantages

1)It cannot alone satisfy all approaches of the readers except the title approach.

4. Alphabetical Subject Catalogue

It is a list of books in a collection, each entered under the name of the specific subject as a heading, the entries being arranged alphabetically. Several books on the same subject will be brought together in the catalogue. When there is more than one book on one subject, the author of the book is taken to determine the alphabetical order. If the author's name is common for several books, then the title of the book is taken in to account for arrangement of entries.

5. Dictionary Catalogue

It is a catalogue in which all the entries (authors, title, subject, series etc.) and their related references are arranged together in one alphabetical reference. It resembles arrangement of entries in a dictionary where the words are strictly arranged alphabetically. The various entries of this catalogue are arranged just like a dictionary that is why it is called dictionary catalogue.

Features

i) It is a mixed type of catalogue, where we find two distinct approaches merged together. It is a combination of two distinct and different approaches, the author and title approach for the reader who knows the book by the author s/he wants, the subject approach of the reader who does not know either the name of author or title of the book but wants material on some definite subject.
ii) As a result of this type of arrangement quite unrelated headings will come together and related headings will be dispersed (e.g. classification and cataloguing; flowers and rose will be dispersed.)
iii) It takes its name from its arrangement which follows the simple alphabetical order of entries.
iv) So far the subject entries are concerned, it follows the principle of specific subject heading. It should be entered under the specific subject.
v) Dictionary catalogue provides an elaborate scheme of cross reference to bring together scatted related subjects and to correlate and unify the entries in order to bring systematic and logical order.
vi) A dictionary catalogue with cross references is called syndetic or connective catalogue.
vii) A dictionary catalogue is divided into two files; one for author, title, series and collaborator entries and another for subject entries.

Advantages

i) It is the most popular form of catalogue used in public, school and college libraries, and even in university libraries. Its popularity is due to its arrangement like a dictionary i.e. in alphabetical order.
ii) It can satisfy the different specific needs of the readers.
iii) The users need not be aware of class numbers to refer this catalogue.
iv) With the help of cross references and general references, readers are guided from one heading to another heading.
v) Direct approach on any specific subject can be satisfied easily e.g. if a reader wants books on “ CRICKET” he will refer the catalogue directly under this term and at once know all the books available on “ CRICKET” in the library.

Disadvantages

i) For readers who need information on a subject with all its ramifications, the dictionary catalogue is most difficult to use. It is slower in yielding information and less satisfactory in its result than the classified form.

ii) Extensive use of cross references to bring together the related subjects together results in the catalogue becoming bulky. Its maintenance is more difficult. Moreover the cross references often proves to be tire some.

iii) It is a tedious and time consuming affair on the part of the readers to find out information on the various aspects of a particular subject and its related subjects from this catalogue.

iv) Dictionary catalogue suffers from all the consequences of excessive dependence on verbalisation.

v) Replacing the old subject terms by new subject terms is a tedious and time consuming process.

6. Classified Catalogue

Classified catalogue provides access to information by subject. It is different from an alphabetical catalogue in that the arrangement is by class numbers. It brings in an artificiality as the user is expected to be aware of the scheme of classification. To help the user, a classified catalogue is in two parts, the other part being alphabetical in nature that guides the user in navigating through the classified part and reaching the desired information.

Learning Outcome 1.2: Identify tools and measurement instruments

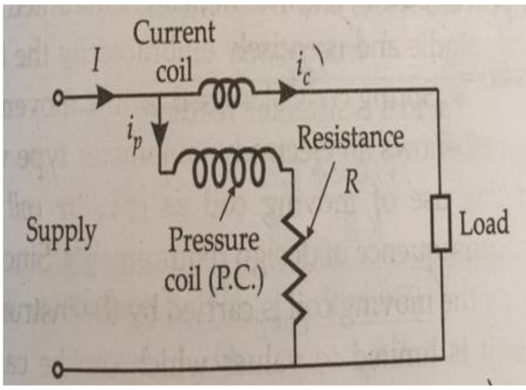
Content/Topic 1. Types of tools and measuring instruments

1. WATT METER

The **wattmeter** is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit.

i. Construction of a Wattmeter

The internal construction of a wattmeter is such that it consists of two coils. One of the coil is in **series** and the other is connected in **parallel.** The coil that is connected in series with the circuit is known as the **current coil** and the one that is connected in parallel with the circuit is known as **the voltage coil.**



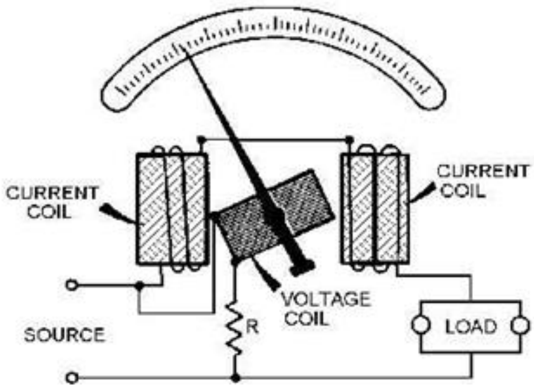


Fig. Wattmeter

ii. Working of a Wattmeter

When the current passes through the current coil, it creates an electromagnetic field around the coil. The strength of this electromagnetic field is directly proportional to the amount of current passing through it.

In case of DC current, the current is also in phase with its generated electromagnetic field. The voltage is dropped across the potential coil and as a result of this complete process, the needle moves across the scale. The needle deflection is such that it is according to the product of the current passing and the voltage dropped, that is, P = VI.

This was the case of DC power. We know that the AC power is given by the formula P = VIcosθ, and we know that this cosθ factor is because of the fact that the current and voltage are not in phase.

But the question that arises here is that how will a wattmeter measure the AC power and this power factor? So the wattmeter simply measures the average power in case if AC power is required.

iii. Three phase power measurement

- ✓ **Voltage and Currents in Star- and Delta-Connected Loads:**

In a three-phase ac system consists of three voltage sources that supply power to loads connected to the supply lines, which can be connected to either delta (Δ) or star (Y) configurations as shown in the figure below.

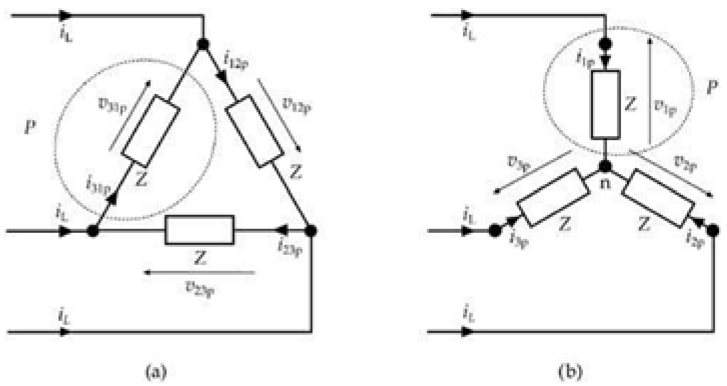


Fig. Delta and star connection

In balanced three-phase systems, the voltages differ in phase 120°, and their frequency and amplitudes are equal. If the three-phase loads are balanced (each having equal impedances), the analysis of such a circuit can be simplified on a per-phase basis.

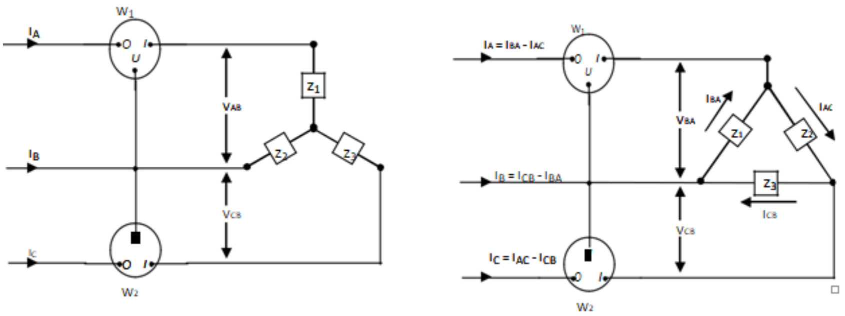
The voltage and current relationships in three-phase ac circuits (in a balanced three-phase system) can be simplified as shown in Table belo

Star-Connected Balanced Load	**Delta-Connected Balanced Load**
Phase current: $I_{1p} = I_{1L}$, $I_{2p} = I_{2L}$, $I_{3p} = I_{3L}$ Line current: $I_L = I_{1L} = I_{2L} = I_{3L}$	Phase current: $I_P = \frac{I_L}{\sqrt{3}}$ Line current: $I_L = I_{1L} = I_{2L} = I_{3L}$ and $I_p = I_{12p} = I_{23p} = I_{31p}$

Star-Connected Balanced Load	**Delta-Connected Balanced Load**
Phase voltage: $V_P = \frac{V_L}{\sqrt{3}}$ Line voltage: $V_L = V_{12} = V_{23} = V_{31}$	Phase voltage: $V_{12} = V_{12p}$, $V_{23} = V_{23p}$, $V_{31} = V_{31p}$ Line voltage: $V_L = V_{12} = V_{23} = V_{31}$ and $V_p = V_{1p} = V_{2p} = V_{3p}$

- ✓ **Three Phase Power Measurement using Two-Wattmeter**

Figure below shows the two-wattmeter connection may be used to determine the power in a three-phase three-wire circuit (balanced or unbalanced).



2. VOLTIMETER

A voltmeter, also known as a voltage meter, is an instrument used for measuring the potential difference, or voltage, between two points in an electrical or electronic circuit. Some voltmeters are intended for use in direct current (DC) circuits; others are designed for alternating current (AC) circuits. Specialized voltmeters can measure radio frequency (RF) voltage.

A basic Analog voltmeter consists of a sensitive galvanometer (current meter) in series with a high resistance. The internal resistance of a voltmeter must be high. Otherwise it will draw significant current, and thereby disturb the operation of the circuit under test. The sensitivity of the galvanometer and the value of the series resistance determine the range of voltages that the meter can display

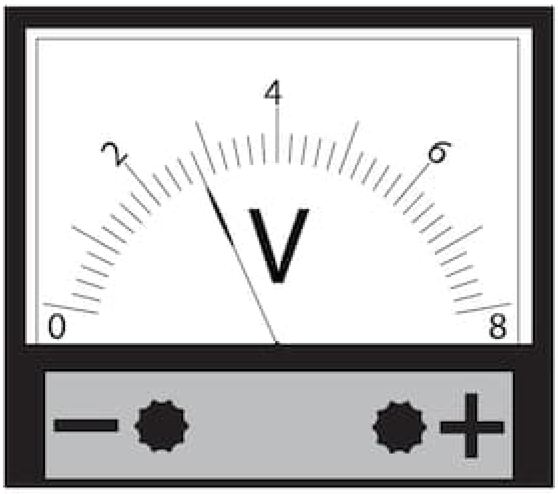


Fig. Voltmeter

3. Earth resistance tester

Fig. Earth resistance tester

The instrument used for measuring the resistance of the earth is known as earth tester. All the equipment of the power system is connected to the earth through the earth electrode. The earth protects the equipment and personnel from the fault current. The **resistance of the earth is very low**. The fault current through the earth electrode passes to the earth. Thus, protects the system from damage.

Before providing the earthing to the equipment, it is essential to determine the resistance of that particular area from where the earthen pit can be dug. The earth should have low resistance so that the fault current easily passes to the earth. The resistance of the earth is determined by the help of earth tester instrument.

4. AMMETER

An ammeter is an instrument used for measuring electric current in units of amperes. An ammeter must be connected in series with the path of the current being measured. Setting the ammeter up in parallel will create a short circuit and will not measure the current correctly.

Fig. Ammeter

1. Working Principle of Ammeter

The main **principle of ammeter** is that it must have a very low resistance and also inductive reactance. Now, why do we need this? Can’t we connect an ammeter in parallel? The answer to this question is that it has very low impedance because it must have very low amount of voltage drop across it and must be connected in series connection because current is same in the series circuit.

Also due to very low impedance the power loss will be low and if it is connected in parallel it becomes almost a short circuited path and all the current will flow through ammeter as a result of high current the instrument may burn. So due to this reason it must be connected in series. For an ideal ammeter, it must have zero impedance so that it has zero voltage drops across it so the power loss in the instrument is zero. But the ideal is not achievable practically.

2. Classification or Types of Ammeter

Depending on the constructing principle, there are many types of ammeter we get, they are mainly:

1. Permanent Magnet Moving Coil **(**PMMC**)** ammeter**.**
2. Moving Iron (MI) Ammeter**.**
3. Electrodynamometer type Ammeter**.**
4. Rectifier type Ammeter**.**

Depending on this, types of measurement we do, we have:

1. DC Ammeter**.**
2. AC Ammeter**.**

5. THERMOMETER

A **thermometer i**s an instrument used for determining temperature; especially : one consisting of a glass bulb attached to a fine tube of glass with a numbered scale and containing a liquid (such as mercury or colored alcohol) that is sealed in and rises and falls with changes of temperature.

Fig. Thermometer

6. FREQUENCY METER

A *frequency meter* is an instrument that displays the *frequency* of a periodic electrical signal. Various types of *frequency* meters are used. Many are instruments of the deflection type, ordinarily used for measuring low *frequencies* but capable of being used for *frequencies* as high as 900 Hz.

Fig. Frequency meter

7. Multimeter

A multi-meter or a multi-tester, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance.

Analog multimeter use a microammeter with a moving pointer to display readings, Digital multimeter (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value. Digital multimeter are now far more common due to their cost and precision, but analog MultiMate's are still preferable in some cases, for example when monitoring a rapidly varying value.

Fig. Multimeter

8. Tachometer

A tachometer (revolution-counter, tach, rev-counter, RPM gauge) is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common.

✓ **Types of Tachometers**

The types of tachometers commonly found are:

- Analog tachometers
- Digital tachometers
- Contact tachometers and
- Non-contact tachometers
- Time Measurement Digital Tachometer
- Frequency Measurement Digital Tachometer

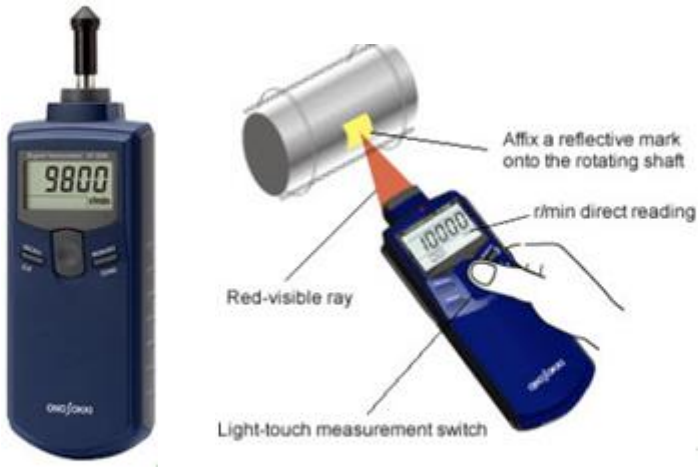


Fig. Tachometer

9. Manometer

A manometer is an instrument used for measuring the pressure of a fluid, consisting of a tube filled with a liquid, the level of the liquid being determined by the fluid pressure and the height of the liquid being indicated on a scale.

Fig. Manometer

Content/Topic 2. Leads/cords

A test probe is a physical device used to connect electronic test equipment to a device under test (DUT). Test probes range from very simple, robust devices to complex probes that are sophisticated, expensive, and fragile. Specific types include test prods, oscilloscope probes and current probes. A test probe is often supplied as a test lead, which includes the probe, cable and terminating connector.

Voltage probes are used to measure voltages present on the DUT. To achieve high accuracy, the test instrument and its probe must not significantly affect the voltage being measured. This is accomplished by ensuring that the combination of instrument and probe exhibit a sufficiently high impedance that will not load the DUT. For AC measurements, the reactive component of impedance may be more important than the resistive.

Simple test leads

Fig. Test leads

A typical voltmeter probe consists of a single wire test lead that has on one end a connector that fits the voltmeter and on the other end a rigid, tubular plastic section that comprises both a handle and probe body. The handle allows a person to hold and guide the probe without influencing the measurement (by becoming part of the electric circuit) or being exposed to dangerous voltages that might cause electric shock. Within the probe body, the wire is connected to a rigid, pointed metal tip that contacts the DUT. Some probes allow an alligator clip to be attached to the tip, thus enabling the probe to be attached to the DUT so that it need not be held in place.

Test leads are usually made with finely stranded wire to keep them flexible, of wire gauges sufficient to conduct a few amperes of electric current. The insulation is chosen to be both flexible and have a breakdown voltage higher than the voltmeter's maximum input voltage. The many fine strands and the thick insulation make the wire thicker than ordinary hookup wire.

Two probes are used together to measure voltage, current, and two-terminal components such as resistors and capacitors. When making DC measurements it is necessary to know which probe is positive and which is negative, so by convention the probes are colored red for positive and black for negative. Depending upon the accuracy required, they can be used with signal frequencies ranging from DC to a few kilohertz.

When sensitive measurements must be made (e.g., very low voltages, or very low or very high resistances) shields, guards, and techniques such as four-terminal Kelvin sensing (using separate leads to carry the measuring current and to sense the voltage) are used.

Content/Topic 3. Elaboration of measurement protocol

Measurement protocol is a set of rules which your application must follow in order to send raw hit data directly to the Google Analytics server. Measurement protocol is used and beneficial for implementing cross-device tracking.

- ✓ **Electrical breakdown measurement protocol**

Failure of electrical insulation properties of insulating materials is known as “breakdown”. There are two kinds of breakdown:

•**Global breakdown:** it causes the complete failure of the electrical insulation between two electrodes.

•**Local breakdown**: it causes the failure of the insulating properties of the material in a selected area. It is also called “Partial Breakdown” (PB).

Inside the TeaM Cables project only the global breakdown is analyzed.

It is worth noting that the dielectric strength of an insulating material varies with: the thickness of the material, area and geometry of the electrodes. Measurement is done in, at least, five different points of the specimen.

Specifications:

1. Test voltages from 0 to 75 kV rms

2. Voltage rate adjustable 0.5 –10 kV/s

3. Accuracy 0 –75 kV ± 1kV

4. Resolution 0.1 kV

5. Switch-off time <10µs

Samples are placed between the electrodes inside a liquid dielectric and a progressive AC 50Hz voltage at a uniform rate of 1.5 kV/s from zero is applied until breakdown. This rate is set according to the standard ASTM D149 -97a (2004) which states: "in establishing a rate initially in order for it to be included in a new specification, select a rate that, for a given set of specimens, will give an average time to breakdown of between 10 and 20 s".

In the end a Weibull distribution model is used to analyze lifetime statistics, according to IEC 62539-2007 standard. From this analysis, two parameters are evaluated:

•**Alpha parameter:** scale parameter providing the Breakdown Voltage

•**Beta parameter**: slope parameter

✓ **Dielectric spectroscopy measurement protocol**

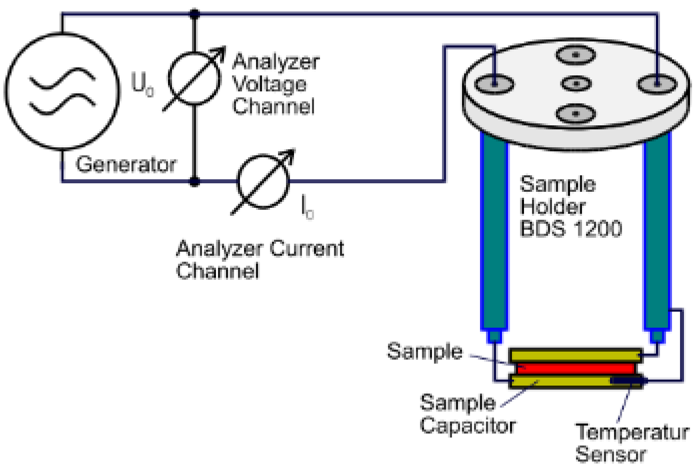
Dielectric spectroscopy (DS, sometimes called impedance spectroscopy) measures the dielectric response of a medium as a function of frequency. It is based on the interaction of an external field with the electric dipole moment of the specimen, i.e. electrical polarization. This technique measures the impedance of a system over a range of frequencies, and therefore the frequency response of the system. This experimental setup allows the evaluation of:

•Capacitance

•Dissipation factor (tan δ)

•Complex permittivity (ε' and ε'') in the frequency range between 10^{-2} -10^{6}Hz.

The measurement principle is shown in the following figure.



- ✓ **Charging/Discharging currents (CDC) measurement protocol**

Standard: ASTM D 257-07 “DC Resistance or Conductance of Insulating Materials”

The CDC measurement procedure is made up of two phases:

1. Polarization phase: the DC voltage is switched on and the polarization process begins. An electrometer acquires the measured current (usually nA) as a function of time;

2. Depolarization phase: the DC voltage is switched off and the specimen is short-circuited. The depolarization current is registered until it reaches zero A.

- ✓ **Insulation resistance measurement protocol**

Standard: the same as for CDC measurements. DC voltage is set at 100, 500 and 1000 Volts (depending on the kind of cable tested as requested). During the polarization phase current values (in A) are measured at 30, 60, 300 secs as requested by the TeaM Cables project.

In the end R_{insul} is obtained as follows:

$$R_{insul}(\Omega) = \frac{Voltage\ (V)}{Current\ (A)}$$

Learning Outcome 1.3: Arrange materials and tools into the working area

Content/Topic 1. Selection of tools and materials to be used in measuring and instrumentation

The selection of measuring instruments for linear measurements, takes the following main factors into account: manufacturing program, the construction features of the details and manufacturing accuracy the tolerance zone (IT), measuring instrument error and the measuring costs.

In the single production companies the special measurement instruments are inapplicable, so it is recommended the dimensions control of manufacturing products to be made using universal measuring equipment (calipers, micrometers, indicating internal gages i.e.). In the serial production the main measurement testing and control instruments are limit gauges, measurement templates and semiautomatic measurement instruments.

For the selection of measurement instruments the set of metrological, exploitation and

Economical indices are reviewed. The metrological indices are: scale interval, measurement method, accuracy, measurement range (interval). The exploitation and the economic indices are the cost and the reliability of measurement instruments, running time before repair is needed, inspection intervals, easy to use, inspection and repair costs including the measurement instrument delivery costs to the place for inspection and back (Fig. 1.) [1]. Fig. 2 shows the required information for the preliminary selection of measurement instruments.

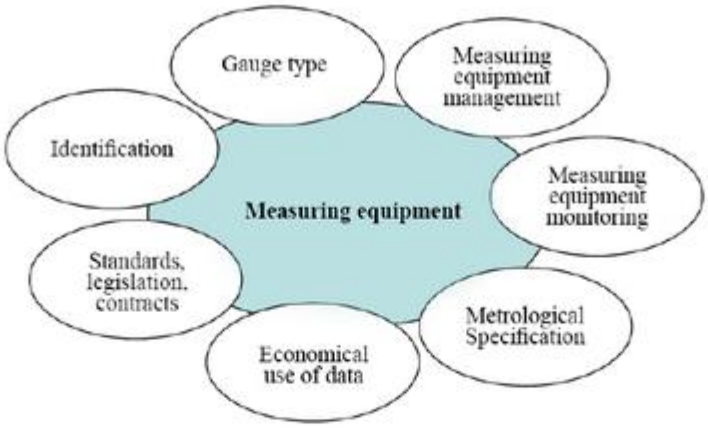


Fig. 1. Information about the measuring equipment

The purpose of preliminary selection of measurement instruments is to reduce the possible solutions when selecting the proper measuring equipment. For the preliminary selection of measurement instruments the main criteria are taken into account, which include organization and technical criteria. This criteria may be arranged by priority (Fig. 2) [1]. Fig. 3 shows the factors, which are taken into account in the selection of measuring instruments.

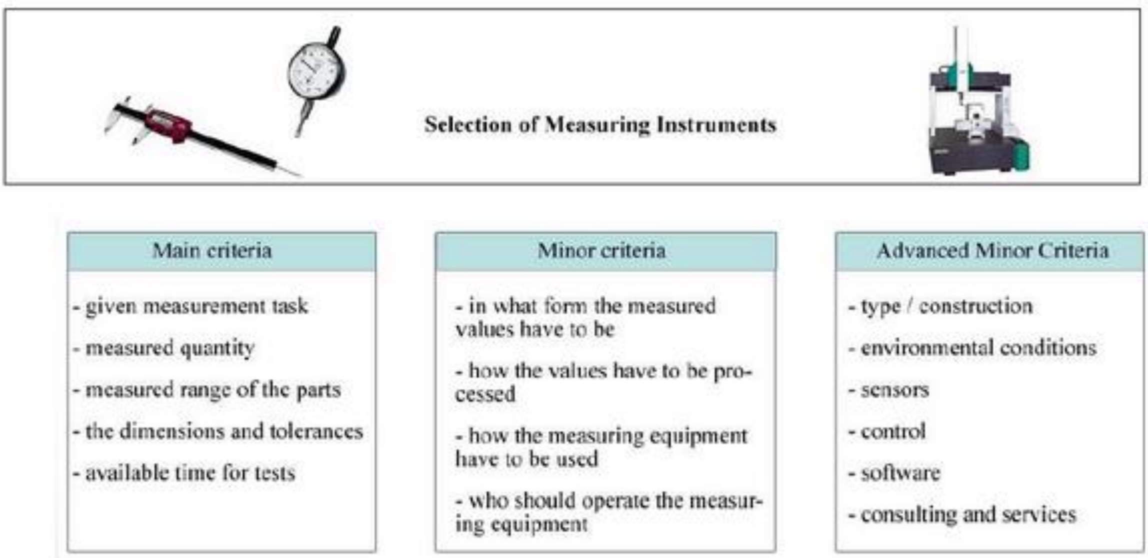


Fig. 2. Criteria for selection of measuring equipment

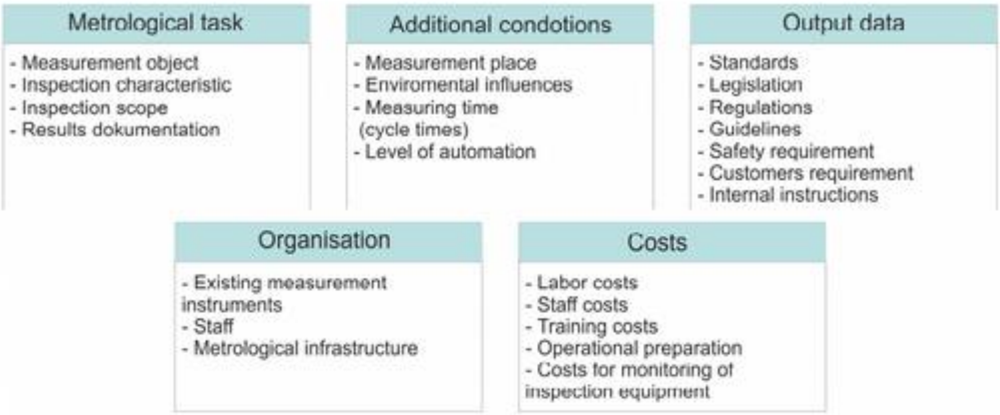


Fig.3. Factors for selection of measurement instruments [1]

Content/Topic 2.Disposition of tools and materials according to their function workplace clearing

1. Place of Working

Whenever possible the preferred place of working on live equipment is the workshop.

- **Equipment**

The correct test equipment must be used when working live. The equipment and probes must be of sufficient capacity for voltage and current, and be in good condition. Where possible high voltage probes should be attached with any electrical power removed and charge storage devices discharged. Protective devices should be used if possible but not be wholly relied upon (see section on RCD Protected Outlets and Other Protective Devices).

2. Precautions

a) Consider any dangers. This will normally be done quite quickly by the individual technician. Questions to ask yourself could consist of the following:

- Can the work be done with the equipment dead?
- Am I authorised to conduct live working at this potential?
- Should I be accompanied by a colleague and is someone available to assist in an emergency?
- Is it absolutely necessary to work on or near equipment that is live at dangerous voltage or current levels?
- Have suitable precautions been taken to avoid injury?

- Am I competent to carry out this work unsupervised?
- Is there room to move or stand back in case of a problem or is there a risk of being knocked by a passerby?
- Is the area cluttered with perhaps bottles of chemicals?
- Are you familiar with the appliance?
- Are the voltages/currents excessive such as in X-Ray or Laser equipment?
- Is the test equipment adequate?
- Is someone available to assist in an emergency?
- Could the lights be accidentally switched off by leaving you in the dark?
- Does the area need to be cordoned off to prevent others from entering and risking themselves or the person working?

b) Set in place adequate precautions to prevent danger to yourself and others. These may include:

- The use of RCD‘s or isolating transformers.
- The use of lockouts, barriers and signs.
- The use of suitable insulation to cover dangerous terminals.
- Powering the circuit from a lower voltage. EG in some electronic devices you can by-pass the appliances built-in mains driven power supply and instead attach a bench power supply thus eliminating the mains voltages form the device.
- Be sure to familiarise yourself with the type of equipment under test. EG does it generate high voltages internally?
- Whenever possible attach probes to H.V. terminals when the equipment is dead.
- Use safety glasses where a danger of arcing exists.
- Do not work alone and ensure that someone is aware that you are working on live equipment and the location and nature of the equipment. This should consist of telling the supervisor and the person responsible for the area you are working. If necessary work in pairs**.**
- Do not leave exposed live terminals unattended even for a moment. If you must leave the power on whilst not in attendance then dangerous terminals must be adequately covered by replacing and securing the covers. Persons within the area must be made aware of the danger by the use of signs such as Danger - Electric Shock Risk‘ or Danger -

Live Conductors' placed adjacent to the equipment and where necessary kept out by the use of suitable barriers. Equipment being tested overnight must have all their terminals securely covered and adequate warning signs and barriers used.

- If there is a chance of insufficient light in the event of a main lighting failure then have a spare lamp operating from a local socket separate from the main lighting circuit.

c) Ensure that the test equipment you use:

- Is suitable for the purpose.
- Is not damaged and that all protective elements are intact. EG has someone removed the earth from the oscilloscope?
- Meets required standards. Equipment purchased for your use should always meet the required standards. You must not use your own equipment unless it has first been approved by the supervisor.

3. Non-Live Working (Permanently Connected Mains Connections)

The major hazard is accidental switching on of the isolators by persons other than the technician carrying out the work. This may be because the technician has left the area for any reason and an individual unknowingly switches on the power to get a service running again. The technician then assumes that the equipment is still in the same condition as when left and is then exposed to the danger of electric shock. Further dangers include the risk of charged capacitors.

Other non-electrical dangers are the changing of saw blades on a circular saw, changing the head on a milling machine or chuck on a lathe etc. This type of work involves working with the hands in and around the rotating mechanism. If the power is accidentally applied then serious damaged can be done to the individual.

Precautions

- Switch off the power at the isolator and lock it off with appropriate padlocks. If more than one person is working then it is preferable that each should have their own padlock.
- Verify using an appropriate tester that the equipment is in fact dead.
- Discharge any capacitors using a recognized method. Do not short with a screwdriver.

- Use appropriate notices such as ‗Danger - Men working on electrical circuits'

4. Working within the Workshop

The major hazards around the workshop are injuries from rotating or other machinery; slipping, tripping or falling; solder fumes; paint, lacquer and solvent fumes; electric shock; burns & fire; injury through lifting.

Precautions

- Keep walkways clear from obstructions and clear spills immediately.
- Use steps or ladders to reach places above head height. Do not use stools or chairs.
- Use fume extractors whilst soldering so as to draw the solder fumes away from the face.
- Use eye, face and hand protection where a risk of damage or contamination is possible whilst operating machinery or where a risk of explosion exists as in changing high pressure lamps or vacuum tubes (CRT's).
- Wear eye protection when machinery such as drills or lathes are operating.
- Keep long hair, ties ETC away from rotating machinery. Hair should be tied-up. Ties should preferably be removed or at worst kept within the overall and tucked into shirt. Clip-on ties can be used.
- Disconnect power to machinery when changing tools ETC by locking off the isolator with a padlock.
- Dispose of sharp material appropriately, use the metal swarf bins' adjacent to the lathes/milling machines.
- Use aerosols such as butane, solvents, lacquers and paints in well ventilated areas and not in the paint store. The paint spray booth is the designated area for spray painting. As well as the fumes which can be harmful these are generally flammable. An example of a risk of fire from an aerosol is the use of switch cleaner on contacts which may arc causing sparks; allow time for the propellant to evaporate before applying power. This could mean times up to 15 minutes in areas with little air flow.
- Before using a power tool or any portable electrical appliance check that it is in good condition by inspecting the cable and plug for cuts, fraying or breakage. Look for the Tested label. Do not use it if it does not have an up-to-date Tested label or if the

cable/plug appears damaged. The criteria for an up-to-date test label would be if the tested date is within 12 months.

- Always fill gas soldering bolts in a well-ventilated area and do not near any naked flames. They should be used solely for the purpose they were bought for and not as a cigarette lighter. They should not be carried in the pocket in case of fuel leakage.

Learning Outcome 1.4: Identify PPE (Personal Protective Equipment)

Content/Topic 1. Safety equipment used for measurement and instrumentation

Definition: PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety for workers from hazard. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing, respirators, goggles, face masks, gloves, footwear and aprons.

1. Overcoat and overall

An overcoat is a type of long coat intended to be worn as the outermost garment, which usually extends below the knee. Overcoats are most commonly used in winter when warmth is more important. They are sometimes confused with or referred to as topcoats, which are shorter and end at or above the knees.

2. Gloves

This is for Hand and Fingers protection from injuries in the work place.

Fig. safety gloves

3. Safety shoes

Safety shoes or strong/rubber boots: Those are for foot protection from injuries.

Figure. Safety shoes

4. Helmet

Those are for Head protection from any dropped material or tools to the head, it is important to plumbers who need to spend time on rooftops, up ladders and scaffoldings.

Figure. Safety helmet

5. Earmuff

Safety earplugs: Those are for ear protection from noise.

Figure. Earmuff

6. Goggles

Safety goggles: those are for eye protection from eyes injuries, resulting in pain, discomfort, loss of income and even blindness

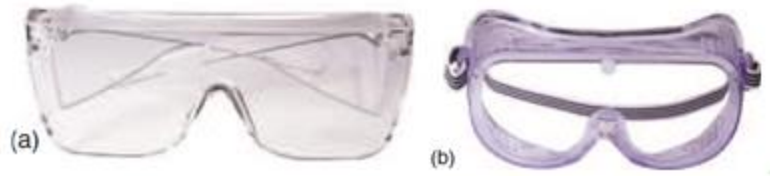


Figure. Safety goggles.

7. Nose protection mask

Respirator protection: this one is used to prevent the microbes and germs from different area

Figure. Respirator protection

Use Safety equipment

Once the hazards of a workplace have been identified, (Safety Person or designated person) will determine if the hazards can first be eliminated or reduced by methods other than PPE, i.e., methods that do not rely on employee behavior, such as engineering controls (refer to Appendix B Controlling Hazards).

If such methods are not adequate or feasible, then (Safety Person or designated person) will determine the suitability of the PPE presently available; and as necessary, will select new or additional equipment which ensures a level of protection greater than the minimum required to protect our employees from the hazards. Care will be taken to recognize the possibility of multiple and simultaneous exposure to a variety of hazards. Adequate protection against the highest level of each of the hazards will be recommended for purchase.

All personal protective clothing and equipment will be of safe design and construction for the work to be performed and will be maintained in a sanitary and reliable condition. Only those items of protective clothing and equipment that meet NIOSH or ANSI (American National Standards Institute) standards will be procured or accepted for use. Newly purchased PPE must conform to the updated ANSI standards which have been incorporated into the PPE regulations, as follows:

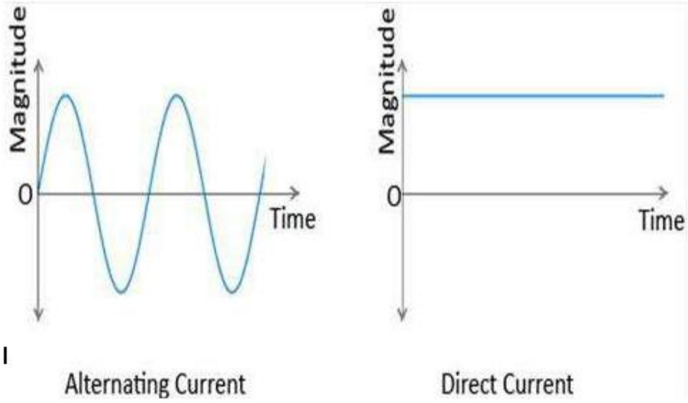
- Eye and Face Protection
- Head Protection
- Foot Protection
- Hand Protection

Affected employees whose jobs require the use of PPE will be informed of the PPE selection and will be provided PPE by (Name of your business) at no charge. Careful consideration will be given to the comfort and proper fit of PPE in order to ensure that the right size is selected and that it will be used.

Learning Outcome: 1.5 Identify electrical Energy systems

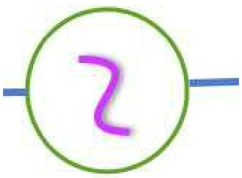
Content/Topic 1. Difference between AC system and DC system

The difference between AC and DC mainly includes the following



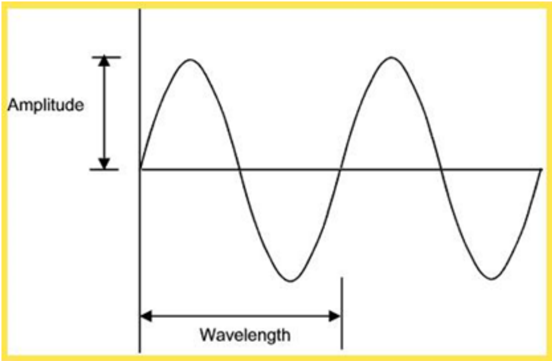
i. Alternating Current (AC)

Alternating current is defined as the flow of charge that changes direction periodically. The result obtained will be, the voltage level also reverses along with the current. Basically AC is used to deliver power to industries, houses, office buildings, etc.



- **Generation of AC**

AC is produced by using called an alternator. It is designed to produce alternating current. Inside of a magnetic field, a loop of wire is spun, from which induced current will flow along the wire. Here the rotation of the wire may come from any no of means i.e. from, a steam turbine, flowing water, a wind turbine and so on. This is because the wire spins and enters into different magnetic polarity periodically, the current and voltage alternates in the wire.



From this, the generated current can be of many waveforms like sine, square and triangle. But in most of the cases sine wave is preferred because it is easy to generate and calculations can be done with ease. However the rest of the wave requires an additional device to convert them into respective waveforms or the shape of the equipment has to be changed and the calculations will be too difficult. Description of Sine waveform is discussed below.

- **Describing a Sine Wave**

Generally, AC waveform can be understood easily with the help of mathematical terms. For this sine wave the three things which are required are amplitude, phase and frequency. By looking at just voltage, sine wave can be described like the below mathematical function:

$V(t) = VP \sin(2\pi ft + \emptyset)$ Where,

V(t): It is a function of time a voltage. This means that as time changes our voltage also changes. In the above equation the term which is right of the equal sign describes how the voltage changes over time.

VP: It is the amplitude. This states how maximum the voltage the sine wave could reach in either direction, i.e. -VP volts, +VP volts, or somewhere in between.

The function of $\sin(2\pi ft + \emptyset)$ states that the voltage will be in the form of a periodic sine wave and will act as a smooth oscillation at 0V.

Here 2π is constant. It converts the frequency from cycles in hertz to angular frequency in radians per second.

Here f describes the sine wave frequency. This will be in the form of units per second or hertz.

The frequency tells how many times a particular waveform occurs within one second.

Here t is a dependent variable. It is measured in seconds. When the time varies the waveform also varies.

The ϕ describes about the phase of the sine wave. Phase is defined as how the waveform is shifted with respect to time. It is measured in degrees. The periodic nature of the sine wave shifts by 360° it becomes same waveform when shifted by 0°.

For the above formula, the real time application values are added by taking United States as a reference.

Root mean square (RMS) is another small concept which helps in calculating the electrical power. $V(t) = 170 \sin(2\pi 60t)$

The other waves, i.e. triangle and square are shown below:

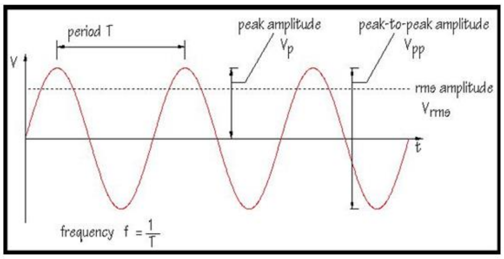


Fig.RMS Sine Waveform

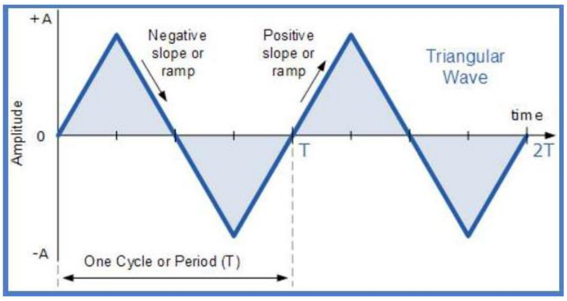


Fig.Triangle Waveform

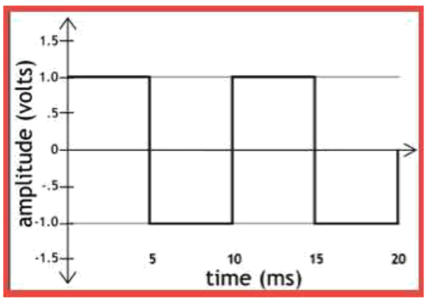


Fig. Rectangular waveform

- **Applications of AC**

- Home and office outlets are used AC.
- Generating and transmission of AC power for long distances is easy.
- Less energy is lost in electrical power transmission for high voltages (> 110kV).
- For higher voltages imply lower currents, and for lower currents less heat is generated in the power line which is obviously due to low resistance.
- AC can be easily converted from high voltage to low voltage and vice versa with the help of transformers.
- AC powers the electric motors.
- It is also useful for many large appliances like refrigerators, dishwashers etc.

ii. Direct Current

Direct current (DC) is the movement of electric charge carriers, i.e. electrons in a unidirectional flow. In DC the intensity of the current will vary along with time, but the direction of movement stays the same in all time. Here DC is referred to voltage whose polarity never reverses.

Content/Topic 2. The passive Component of AC/DC

1. Passive components

Electronic components are basic electronic element or electronic parts usually packaged in a discrete form with two or more connecting leads or metallic pads.

Electronic Components are intended to be connected together, usually by soldering to a printed circuit board (PCB), to create an electronic circuit with a particular function (for example an amplifier, radio receiver, oscillator, wireless). Some of the main Electronic Components are: resistor, capacitor, transistor, diode, operational amplifier, resistor array, logic gate etc.

Electronic Components are of 2 types: Passive and Active

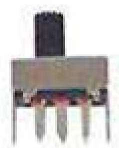
Passive electronic components are those that do not have gain or directionality. They are also called Electrical elements or electrical components. e.g. resistors, capacitors, diodes, Inductors.

Active electronic components are those that have gain or directionality. e.g. transistors, integrated circuits or ICs, logic gates. Here are some of the Electronic Components and their functions in electronics and electrical:

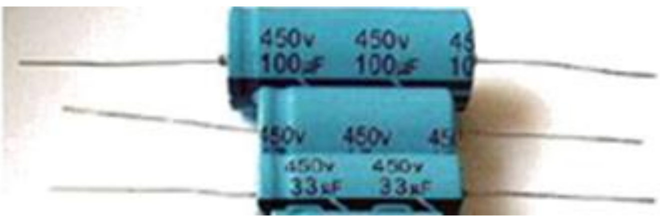
Terminals and Connectors: Components to make electrical connection.

1. Resistors: Components used to resist current.

2. Switches: Components that may be made to either conduct (closed) or not (open).



3. Capacitors: Components that store electrical charge in an electrical field.

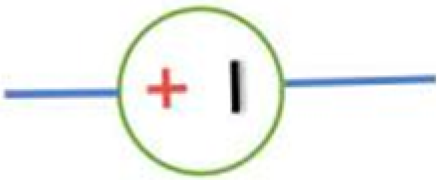


4. **Magnetic or Inductive Components:** These are Electrical components that use magnetism

5. Diodes: Components that conduct electricity in only one direction.

Content/Topic 3. DC Source

In a DC circuit, electrons emerge from the minus or negative pole and move towards the plus or positive pole. Some of the physicists define DC as, it travels from plus to minus.



Generally the basic source of direct current is produced by batteries, electrochemical, and photovoltaic cells. But AC is most preferred across the world. In this scenario AC can be converted to DC. This will happen in multiple steps. Initially, power supply consists of a transformer, which later converted into DC with the help of a rectifier. It prevents the flow of current from reversing and a filter is used to eliminate current pulsations in the output of the rectifier. These are the phenomenon how AC is converted into DC.

1. Batteries

Battery is an electrical device used for storing electricity. Batteries are classified into primary and secondary forms:

• **Primary batteries** are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless.

• **Secondary batteries** can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times. Some types of primary batteries used, for example, for telegraph circuits, were restored to operation by replacing the electrodes. Secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion.

2. AC/DC Converter

AC-DC converters are electrical circuits that transform alternating current (AC) input into direct current (DC) output. They are used in power electronic applications where the power input a 50 Hz or 60 Hz sine-wave AC voltage that requires power conversion for a DC output. AC to DC converters uses rectifiers to turn AC input into DC output. These devices are used to power computers or computer peripherals.

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.

3. Direct Current (DC) Generator

Dc generator is a machine which converts mechanical energy into electrical energy in form of direct current (Dc).

D.C. generators are classified according to the method of their field excitation. These groupings are:

(i) Separately-excited generators, where the field winding is connected to a source of supply other than the armature of its own machine.

(ii) Self-excited generators, where the field winding receives its supply from the armature of its own machine, and which are sub-divided into (a) shunt, (b) Series, and (c) compound wound generators.

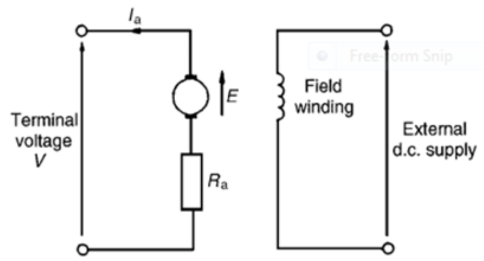
3.1 Types of dc generator

(i) Separately-excited generator

A typical separately-excited generator circuit is shown in Figure below. When a load is connected across the armature terminals, a load current Ia will flow. The terminal voltage V will fall from its open-circuit e.m.f (E) due to a volt drop caused by current flowing through the armature resistance, shown as Ra.

i.e. terminal voltage, $V = E - I_a R_a$

or generated e.m.f., $E = V + I_a R_a$



(ii) Self-excited generators

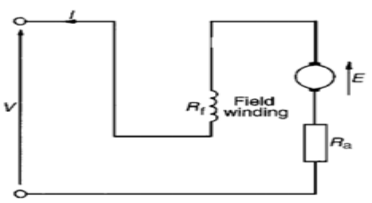
- ✓ **Shunt wound generator**

In a shunt wound generator the field winding is connected in parallel with the armature as shown in figure below, the field winding has a relatively high resistance and therefore the current carried is only a fraction of the armature current. For the circuit shown in Figure above, terminal voltage, V=E−IaRa or generated e.m.f. E=V+IaRa

Ia=If +I from Kirchhoff's current law, where Ia=armature current, If =field current (=V/Rf) and I=load current.

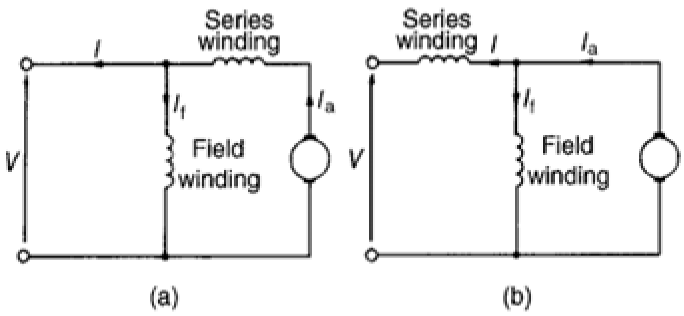
- ✓ **Series-wound generator**

In the series-wound generator the field winding is connected in series with the armature.



✓ **Compound-wound generator**

In the compound-wound generator two methods of connection are used, both having a mixture of shunt and series windings, designed to combine the advantages of each. Figure below (a) shows what is termed a long-shunt compound generator, and Figure (b) shows a short-shunt compound generator. The latter is the most generally used form of DC generator.



The main difference between AC and DC is discusses in the following comparison chart

S No		Alternating Current	Direct Current
1	The amount of energy that can be carried	It is safe to transfer over longer city distances and will provide more power.	Practically the voltage of DC cannot travel very far until it begins to lose energy.
2	The cause of the direction of flow of electrons	It is denoted rotating magnet along the wire.	It is denoted steady magnetism along the wire
3	Frequency	The frequency of alternating current will be either 50Hz or 60Hz depending upon the country.	The frequency of direct current will be zero.
4	Direction	It reverses its direction while flowing in a	It only flows in one direction in the circuit.

		circuit.	
5	Current	It is the current of magnitude which is varying with time	It is the current of constant magnitude.
6	Flow of Electrons	Here electrons will keep switching the directions – forward and backward.	Electrons move steadily in one direction or _forward'.
7	Obtained from	The source of availability is A.C Generator and mains.	The source of availability is either Cell or Battery.
8	Passive Parameters	It is Impedance.	Only Resistance
9	Power Factor	It basically Lies between 0&1.	It will be always 1.
10	Types	It will of different types like Sinusoidal, Square Trapezoidal, and Triangular.	It will be of Pure and pulsating.

Learning unit 2. Carryout measurements and instrumentation

Learning Outcome 2.1: Describe different methods of measurement systems

Content/Topic 1. Elements of Generalized Measurement System

The physical sciences are called exact sciences, for they give us accurate knowledge. This exactness or accuracy comes from Measurements. The study of physics involved measurements of various types at every stage. So Physics is often called the Science of Measurements.

Determining a quantity or variable using a physical means is called the measurement and the means by which the quantity is determined is called Measuring Instruments.

Thus, an instrument may be defined as a device for determining the value or magnitude of a quantity or variable. An instrument enables a person to determine the value of an unknown quantity

Some of terms are used in the measurement work, which are defined below.

1. True Value: It is the average of an infinite number of measured values.

2. Error: It is the difference between the measured value and the true value.

3. Index Scale: It is the set of marks or divisions.

4**. Index Number:** It is the number of divisions moved.

The essential requirements of a measuring instrument are:

(i) It should not alter the circuit conditions,

(ii) Power consumed by it should be small.

The characteristics of the instrument and the measurement system play an important role in determining the performance of the measurement system. The characteristics of the instruments can be divided into two distinct categories: Static characteristics, and Dynamic characteristics.

1. **Static Characteristics:** The main static characteristics are

(i) Accuracy: It refers to the closeness of an instrument reading to the true value of the quantity or variable under measurement. This term describes the algebraic difference between the indicated value and the true value or theoretical value of the measured. In practice, accuracy is usually expressed as a percentage of full scale output or percent of reading or digits for digital readouts.

(ii) Precision: It refers to the measure of the reproducibility or repeatability of the measurement. It is a measure of the degree to which successive measurements differ from one another. If a number of readings of a voltmeter are taken, then the expected value of 1.0 volt is not obtained on every occasion. A range of values such as 0.99, 1.01, 1.00, 1.02, 0.98, etc. are obtained about the expected value. The effect is termed as a lack of repeatability in the instrument.

(iii) Sensitivity: It is the ratio of the magnitude of the output signal or response to the input signal. It is expressed in mm/A, or counts/volt. In other words, it describes the transfer ratio of the output to the input.

(iv) Resolution: It indicates the smallest change in measurable input to which the instrument will respond.

(v) Linearity: It is the degree to which variations in the output of an instrument follow input variations. It is the uniform displacement. It reflects that the output, in some way, is proportional to the input. The system is said to be linear when the corresponding values of input and output lie on a straight line.

(vi) Drift: It indicates a change of baseline, i.e., change of the output when input is zero, or of sensitivity with time, temperature etc.

(vii) Noise: This is an undesired signal at the output due to either internal source or to interference.

(**viii) Hysteresis:** It is the change of output with some value of input with a different history of input variation.

A hysteresis is observed when the input/output characteristics for an instrument are different when input increases than when the input decreases. It results when some of the energy applied to increase inputs is not recovered when the input is decreased. The phenomenon, which takes place during magnetizing and demagnetizing a magnetic material, is called hysteresis.

(ix) Span: It is the total operating range of the instrument.

(x) Threshold or Dead Time: The threshold of the instrument is the smallest change in the measures which will result in a measurable change in output of the instrument In other words, Threshold or Dead Time can be defined as the time required by an instrument or the measurement system to respond to a change in the measures.

(xi) Saturation: The output is generally proportional to the input. A point is reached when the output of the instrument will no longer increase for the increased input, giving rise to non-linear relationship. The region in which the output does not change with increase in input is called Saturation Region. Saturation Region may also be referred to as Dead Zone. In other words, the Saturation Region or Dead Zone may be defined as the largest change in the input for which there is no output of the instrument.

2. Dynamic Characteristics

It describes the ways in which an instrument or measurement system responds to sudden changes to the input. In general, the dynamic response of the measurement system is expressed in the form of a differential equation. For any dynamic system, the order of the differential equation which describes the system is called the Order of the System.

(i) Zero-order System: It has an ideal dynamic performance, because the output is proportional to the input for all frequencies and there is no amplitude or phase distortion. A linear potentiometer is an example of a zero-order element.

(ii) First-order System: A first-order instrument or system is characterized by a linear differential equation. The temperature transducer is an example of first-order measuring devices, since this is characterized by a single parameter, i.e., time constant.

(iii) Second-order System: This type of system is characterized by the second-order differential equation. The example of the second-order system is the mass-spring system of the measurement of the force. The dynamic characteristics of an instrument or the measurement system are as follows:

(i) Respond Time: It is an important parameter to describe the dynamic response of an instrument. It characterizes the instrument to a step change in the measure (input). It includes rise time, delay time and time constant.

(ii) Fidelity: It is defined as the degree of the measurement system. It indicates changes in the measurement without any dynamic error.

(iii) Measuring Lag: It is the retardation or delay in the response of a measurement system to changes in the measure.

(iv) Dynamic Error: It is the difference between the true value of the quantity under measurement changing with time and the measured value of the quantity. It also referred to as Measurement error.

Other Characteristics

There are other characteristics which determine the performance characteristics and the choice of the instruments. These are:

(i) The Input and the output impedance,

(ii) Overload range,

(iii) Recovery time after overload,

(iv) Excitation voltage,

(v) Reliability,

(vi) Size and weight.

The dynamic behavior of the measurement system is studied in the following two domains:

(i) Time Domain, and (ii) Frequency Domain.

In the Time Domain analysis time is used in the measurement system as an independent variable. The dynamic behaviour of the system is studied as a function of time with the different input signals applied to the measurement system. The different input signals are step, ramp, parabolic and impulse.

The output of the measurement system is expected to follow the input very closely as far as possible. Hence, it is necessary to compare the output and the input variables at all times.

In the Frequency Domain analysis, the frequency is used as an independent variable. The dynamic behaviour of the system is studied with the sinusoidal input signal applied to the measurement system. The resulting output of a linear system is sinusoidal with different from the input waveform in amplitude and phase in the steady state condition.

Most of the measurement systems contain three main functional elements are:

i) Primary sensing element

ii) Variable conversion element &

iii) Data presentation element.

- ✓ **Primary sensing element:**

The quantity under measurement makes its first contact with the primary sensing element of a measurement system i.e., the measured (the unknown quantity which is to be measured) is first detected by primary sensor which gives the output in a different analogous form.

This output is then converted into an electrical signal by a transducer - (which converts energy from one form to another). The first stage of a measurement system is known as a detector

- ✓ **Transducer stage Variable conversion element:**

The output of the primary sensing element may be electrical signal of any form; it may be voltage, a frequency or some other electrical parameter**.**

For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form.

- ✓ **Variable manipulation element:**

The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. It is not necessary that a variable manipulation element should follow the variable conversion element.

Some non-linear processes like modulation, detection, sampling, filtering, chopping etc., are performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system.

This process of conversion is called signal conditioning. The term signal conditioning includes many other functions in addition to

- ✓ **Variable conversion & Variable manipulation**

In fact the element that follows the primary sensing element in any instrument or measurement system is called signal conditioning element

When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function is called a data transmission element.

The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes.

- ✓ This function is done by data presentation element
- ✓ In case data is to be monitored, visual display devices are needed

- ✓ These devices may be analog or digital indicating instruments like ammeters, voltmeters etc
- ✓ In case data is to be recorded, recorders like magnetic tapes, high speed camera & TV equipment, CRT, printers may be used
- ✓ For control & analysis purpose microprocessor or computers may be used.

The final stage in a measurement system is known as terminating stage'.

Content/topic 2. Methods for measurement

There are two methods of measurement: 1) direct comparison with the standard, and 2) indirect comparison with the standard. Both the methods are discussed below:

Measurement of any quantity involves two parameters: the magnitude of the value and unit of measurement. For instance, if we have to measure the voltage we can say it is 220V. Here the value "220" is the magnitude and "V" which stands for "volts" is the unit of measurement.

1) Direct Comparison with the Standard

In the direct comparison method of measurement, we compare the quantity directly with the primary or secondary standard. Say for instance, if we have to measure the length of the bar, we will measure it with the help of the measuring tape or scale that acts as the secondary standard. Here we are comparing the quantity to be measured directly with the standard.

2) Indirect Method of Measurement

There are number of quantities that cannot be measured directly by using some instrument. For instance, we cannot measure the strain in the bar due to applied force directly. We may have to record the temperature and pressure in the deep depths of the ground or in some far off remote places. In such cases indirect methods of measurements are used.

Briefly: 'Direct measurement' refers to measuring exactly the thing that you're looking to measure, while 'indirect measurement' means that you're measuring something by measuring something else.

Content/Topic 3. Types of instruments

i. Mechanical Instruments

Mechanical instruments can be used to measure, record, and trend variations in process parameters, such as pressure, flow, or temperature. In most cases, the instrument will convert mechanical displacement or movement of its sensor into a corresponding proportional movement of a pen or gauge.

Types of mechanical instrument

1. Vernier Caliper

Vernier Caliper is a widely used linear measurement instrument with a least count of 0.02 mm. It is used to measure linear dimensions like length, diameter, and depth.

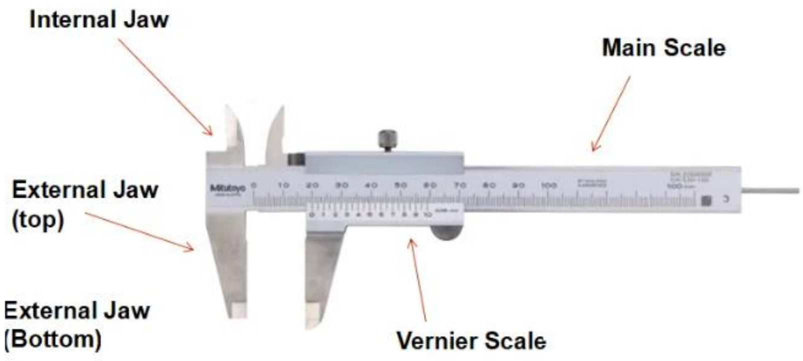


Fig. Vernier caliper

It is Basic Instrument of measurement; consist of two types of scale. The main scale and the Vernier scale that can slide along the main scale. Two types of measurement we can do, the first one is through the external jaw (measure external dimensions) and another one is internal jaw (measure internal dimensions).

2. Outside Micrometer

External Micrometer is also known as Outside Micrometer or External Micrometer. It is used to check outside diameter of circle by the means of accuracy of 0.01 mm or up to 0.001 mm.

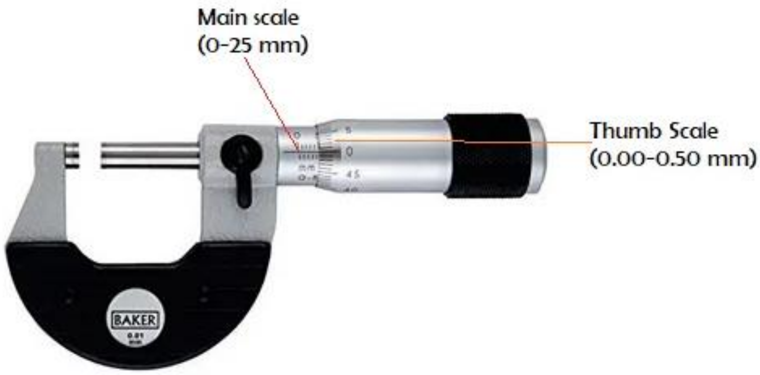


Fig. Outside micrometer

3. Vernier Height Gauge

Vernier height gauge used to measure vertical dimension from reference ground. Vernier Height Gauge consists of a graduated scale or bar is held in a vertical position by a finely ground fixed base. The graduated scale has least count of 0.02 mm like Vernier Caliper has. And the way of taking a reading of measurement in Vernier Height Gauge is same as in Vernier gauge.

Fig. Vernier height gauge

4. Steel Scale

Steel scale is single piece linear measuring instrument. Steel scale indicates two units that are cm and inches, cm division on one side and inches, on another side.

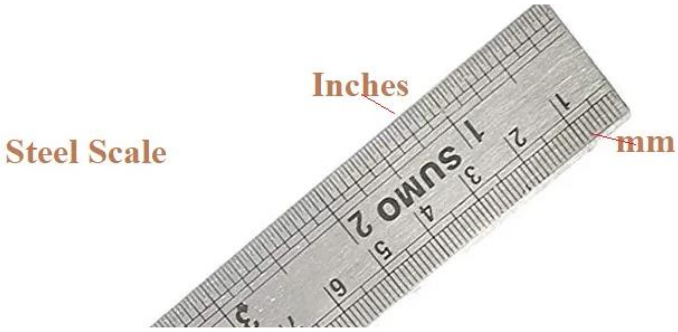


Fig. Steel scale

ii. Electrical Instruments

The electrical instrument is used for measuring electrical quantities likes current, voltage, power, etc. The ammeter, voltmeter, wattmeter are the examples of the electrical measuring instrument. The ammeter measures the current in amps; voltmeter measures voltage and Wattmeter are used for measuring the power.

iii. Electronic Instruments

Electronic measuring instruments have advantages over instruments such as the moving-iron or moving-coil meters, in that they have a much higher input resistance (some as high as 1000 MΩ) and can handle a much wider range of frequency (from d.c. up to MHz).

✓

The digital voltmeter (DVM) is one which provides a digital display of the voltage being measured. Advantages of a DVM over analogue instruments include higher accuracy and resolution, no observational or parallex errors (see Section 10.20) and a very high input resistance, constant on all ranges.

✓

A digital multimeter is a DVM with additional circuitry which makes it capable of measuring a.c. voltage, d.c. and a.c. current and resistance. Instruments for a.c. measurements are generally calibrated with a sinusoidal alternating waveform to indicate r.m.s. values when a sinusoidal signal is applied to the instrument. Some instruments, such as the moving iron and electro-dynamic instruments, give a true r.m.s. indication. With other instruments the indication is either scaled up from the mean value (such as with the rectifier moving-coil instrument) or scaled down from the peak value.

✓

Sometimes quantities to be measured have complex waveforms (see Section 10.13), and whenever a quantity is non-sinusoidal, errors in instrument readings can occur if the instrument has been calibrated for sine waves only. Such waveform errors can be largely eliminated by using electronic instruments.

Learning Outcome 2.2: Handle measuring equipment and devices

Content/Topic 1. Operation of measuring equipment and devices

- ✓ **Watt meter**

A wattmeter does a complex job, measuring the power flowing through an electrical circuit. It simultaneously measures the voltage and current values and multiplies them to give power in watts. The three main types are electro-dynamic, electronic and digital.

- **Electrodynamic**

Electrodynamic wattmeter is a design that goes back to the early 20th century. They work by using three coils: two fixed in series with the electrical load, and a moving coil in parallel with it. The series coils measure current flowing through the circuit, the parallel coil measures voltage. A series resistor limits the current through the moving coil. It's situated between the two fixed coils and is attached to an indicator needle. The magnetic fields in all three coils influence the needle movement. A spring returns the needle to zero when no voltage or current is present. This design is simple, reliable and rugged, though the coils can overheat.

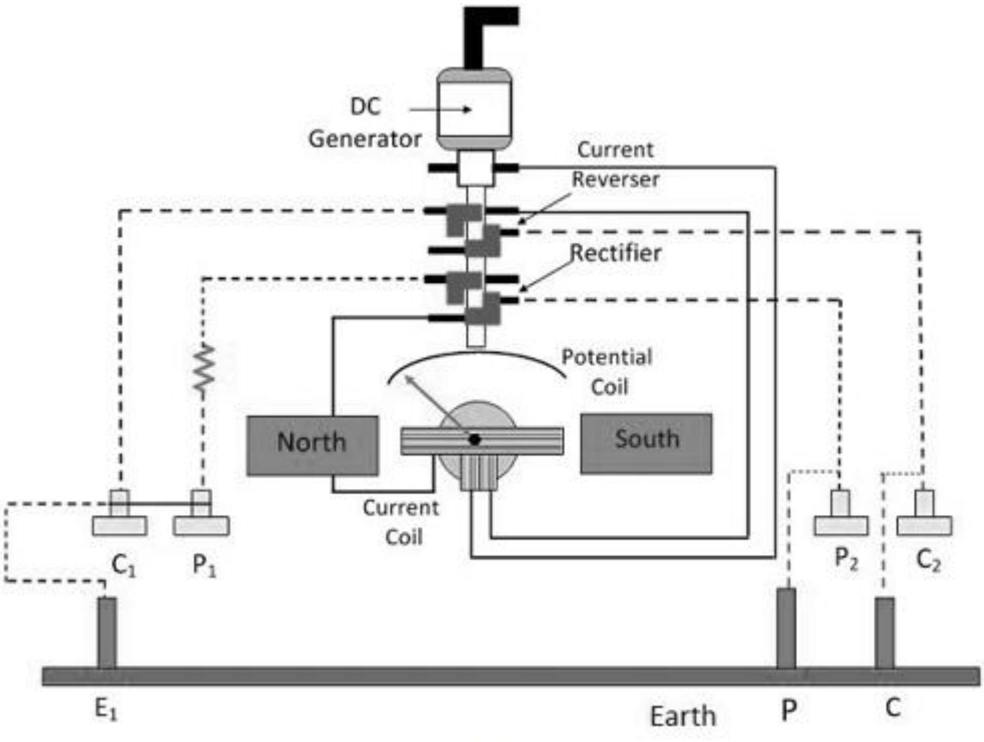
- **Electronic**

People using radio and microwave equipment need to measure watts at frequencies much higher than the power grid's 60 hertz. Electrodynamic wattmeters are fine for AC power-line measurements, but the coils are frequency-dependent parts that don't work for radio. For radio, you need a fully electronic approach. Here, an electronic circuit measures the current and voltage, multiplies the two in another circuit, and delivers the result as a proportional current or voltage to a standard meter movement.

- ✓ **Earth resistance meter**

The earth tester uses the dc generator, rotational current reverser, rectifier, and potential coil. The main parts of this tester are current reverser and rectifier; these two parts are mounted on the dc generator shaft. This tester consists of two pressures coils like p1 and p2 and two current coils like C1 and C2. These two coils are placed across the permanent magnet. Both the pressure and current coils have two terminals, the one end of both coils connected to a rectifier and other ends are connected to earth electrodes.

The potential coil is connected to the dc generator directly and it is placed between permanent magnets 'N' and 'S'. The pointer coil position is fixed on the calibrated scale. The magnitude of the resistance is indicated by the pointer. The resistance of the earth is defined as the ratio of potential to earth electrode and current, or the ratio of voltage and current. The circuit diagram of the earth tester is shown below.



earth-tester

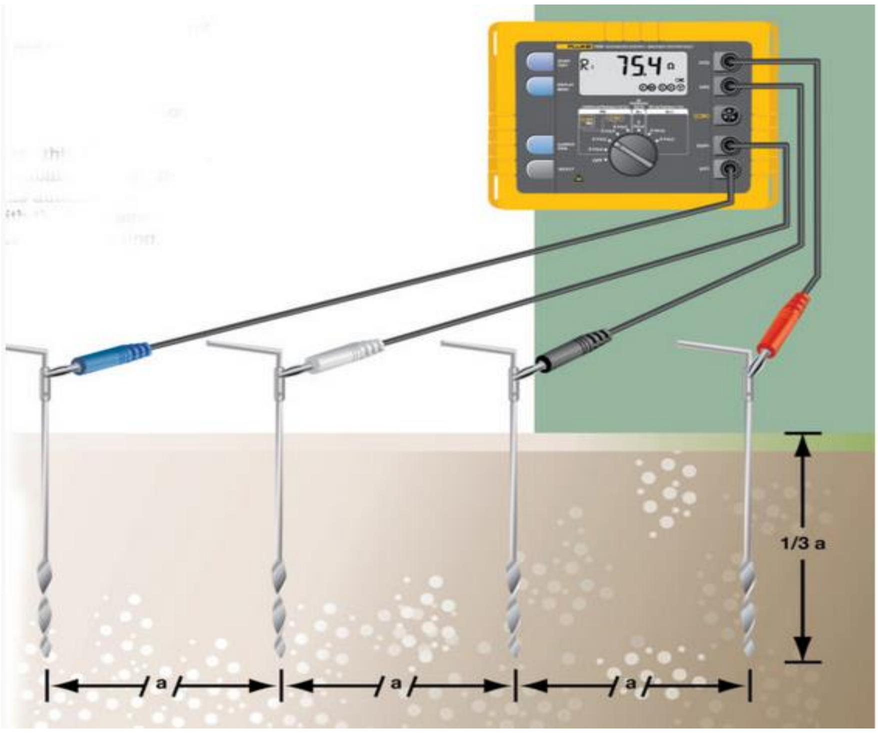
The different power station's earth resistance values are shown below.

Large Power Stations: In large power stations, the earth resistance value is 0.5 ohms

Major Power Stations: In major power stations, the earth resistance value is 1.0 ohms

Small Sub Stations: In small substations, the earth resistance value is 2.0 ohms and in all other cases the value of earth resistance is 8.0 ohms.

To test soil resistivity, connect the ground tester as shown in Fig. below Four earth ground stakes are positioned in the soil in a straight line, equidistant from one another. The distance between earth ground stakes should be at least three times greater than the stake depth. The Fluke1625 earth ground tester generates a known current through the two outer ground stakes and the drop in voltage potential is measured between the two inner ground stakes. The tester automatically calculates the soil resistance using Ohm's Law (V=IR).



- ✓ **Voltmeter**

Voltmeter is a voltage meter. This measures the voltage between the two nodes. We know the unit of potential difference is volts. So it is a measuring instrument which measures the potential difference between the two points.

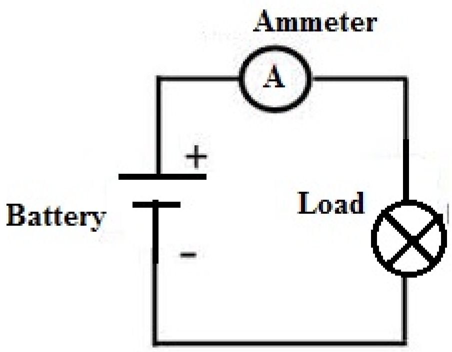
The main principle of voltmeter is that it must be connected in parallel in which we want to measure the voltage. Parallel connection is used because a voltmeter is constructed in such a way that it has a very high value of resistance. So if that high resistance is connected in series than the current flow will be almost zero which means the circuit has become open.

If it is connected in parallel, than the load impedance comes parallel with the high resistance of the voltmeter and hence the combination will give almost the same the impedance that the load had. Also in parallel circuit we know that the voltage is same so the voltage between the voltmeter and the load is almost same and hence voltmeter measures the voltage.

For an ideal voltmeter, we have the resistance is to be infinity and hence the current drawn to be zero so there will be no power loss in the instrument. But this is not achievable practically as we cannot have a material which has infinite resistance.

- ✓ **Ammeter**

The principle of ammeter is that the resistance and inductive reactance must be very low. Ammeter has a very low impedance as the voltage drop across the ammeter should be low. The ammeter cannot be connected in parallel because of the above-mentioned reason. In a series connection, the current will be same. Also connecting an ammeter in parallel may result in short circuit and the current passing through ammeter might burn the instrument. For an ideal ammeter, the impedance must be zero so that the voltage drop across the instrument is zero. The construction of ammeter can be done in two ways like series and shunt. The following circuit represents the basic circuit diagram and the connection of the ammeter circuit in series and parallel are shown below



Once this device is connected in series in the circuit, and then the total measured current will flow through the meter. So the loss of power occurs within ammeter due to their internal resistance & the measured current. This circuit includes less resistance so less voltage drop will occur within the circuit.

- ✓ **Tachometer**

A Tachometer is an instrument measuring the rotation pace of a shaft or disk, as in a motor or different machine. The device generally shows the revolutions in keeping with minute (RPM) on a calibrated analogue dial, however virtual presentations are increasingly more common. Essentially the phrases tachometer and speedometer have identical meaning: a device that measures speed. It's far by way of arbitrary conference that within the automobile world one is used for engine and the other for vehicle velocity. In formal engineering nomenclature, more particular terms are used to differentiate the two.

It produces the voltage consistent with the velocity of the shaft. Power, accuracy, RPM range, measurements and display are the specifications of a tachometer. Tachometers may be analog or digital indicating meters; but, this text focuses handiest at the virtual tachometers. Digital tachometers are divided into four types primarily based at the information acquisition and size strategies.

Tachometers are used to estimate traffic speed and volume (flow). A vehicle is equipped with the sensor and conducts "tach runs" which record the traffic data. These data are a substitute or complement to loop detector data. To get statistically significant results requires a high number of runs, and bias is introduced by the time of day, day of week, and the season. However, because of the expense, spacing (a lower density of loop detectors diminishes data accuracy), and relatively low reliability of loop detectors (often 30% or more are out of service at any given time), tach runs remain a common practice.

Based on the data acquisition technique, the tachometers are of the two type Contact type, Non-Contact types both type are available at Instronline.

There are a vast varieties of techno meter are available with a large array of products list like **See-believe portable digital tachometer, Samson Check Valves, Conductivity Controller, conductivity meters**. You can also find **lockup valve Dealers at Instronline** is portal where you can search and find best suitable model according to your need. ABUSTEK Interface converter is available in Delhi Ncr which is highly in demand Digital Tachometer is basically used for Space Shuttle, Motor Control, Assembly Systems, Data Recording Systems Petrochemical, Air compressors.

The working principle of an electronic tachometer is quite simple. The ignition device triggers a voltage pulse on the output of the tachometer electromechanical component whenever the spark plugs fires. The electromechanical element responds to the common voltage of the series of pulses. It indicates that the common voltage of the pulse teach is proportional to engine pace. The sign from the notion head is transmitted with the aid of general dual screened cable to the indicator.

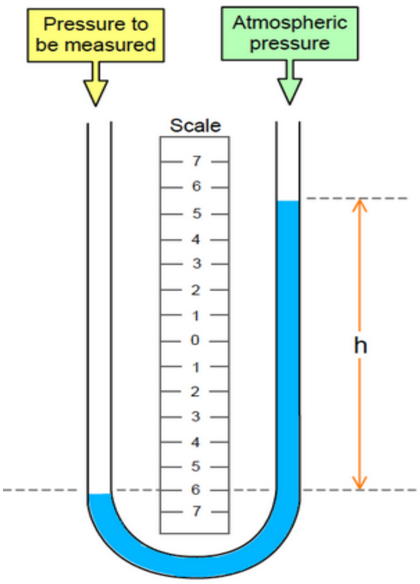
The tachometers are temperature compensated as a way to deal with operations over an ambient temperature range of – 20 to +70°C (-4 to +158°F). It’s all about revolution. Digital tachometers, and all tachometers, measure the revolutions of a spinning object to determine the rate at which it is spinning. Nearly all types of transportation vehicles, from planes to trucks to buses to trains to cars have tachometers. You’ll even find tachometers used for production line checks, monitoring turbines, measuring machine speeds, and maintaining quality control.

✓ **Thermometer**

Today, there are a variety of types of thermometers. The type that most of us are familiar with from science class is the type that consists of a liquid encased in a narrow glass column. Older thermometers of this type used liquid mercury. In response to our understanding of the health concerns associated with mercury exposure, these types of thermometers usually use some type of liquid alcohol. These liquid thermometers are based on the principal of thermal expansion. When a substance gets hotter, it expands to a greater volume. Nearly all substances exhibit this behavior of thermal expansion. It is the basis of the design and operation of thermometers.

As the temperature of the liquid in a thermometer increases, its volume increases. The liquid is enclosed in a tall, narrow glass (or plastic) column with a constant cross-sectional area. The increase in volume is thus due to a change in height of the liquid within the column. The increase in volume, and thus in the height of the liquid column, is proportional to the increase in temperature. Suppose that a 10-degree increase in temperature causes a 1-cm increase in the column's height. Then a 20-degree increase in temperature will cause a 2-cm increase in the column's height. And a 30-degree increase in temperature will cause s 3-cm increase in the column's height. The relationship between the temperature and the column's height is linear over the small temperature range for which the thermometer is used. This linear relationship makes the calibration of a thermometer a relatively easy task.

✓ **Manometer**



The principle of the manometer is that the pressure to be measured is applied to one side of the tube producing a movement of liquid, as shown in figure above. It can be seen that the level of the filling liquid in the leg where the pressure is applied, i.e. the left leg of the tube, has dropped, while that in the right hand leg as risen. A scale is fitted between the tubes to enable us to measure this displacement.

Let us assume that the pressure we are measuring and have applied to the left hand side of the manometer is of constant value. The liquid will only stop moving when the pressure exerted by the column of liquid, H is sufficient to balance the pressure applied to the left side of the manometer, i.e. when the head pressure produced by column " H " is equal to the pressure to be measured.

Knowing the length of the column of the liquid, H, and density of the filling liquid, we can calculate the value of the applied pressure.

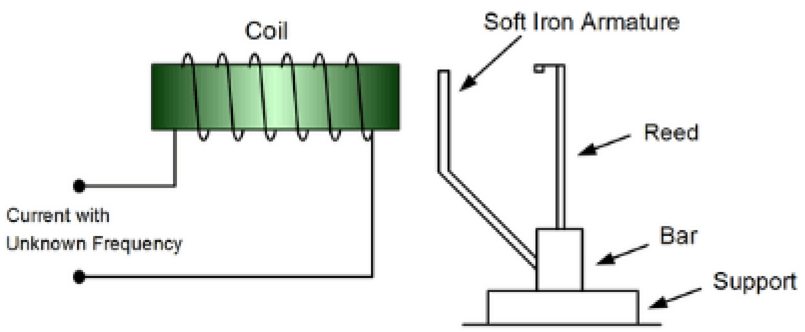
The applied Pressure = $\rho \times g \times h$

y suitable choice of filling liquid, various low ranges of gauge pressure can be measured from about 500 Pa to 1.5 bar. Typical filling liquids commonly used in manometers and their densities.

1. Water (ρ = 1000 kg m^{-3})
2. Oil (ρ can be between 800 and 950 kg m^{-3})
3. Mercury (ρ = 13560 kg m^{-3})

- ✓ **Frequency meter**

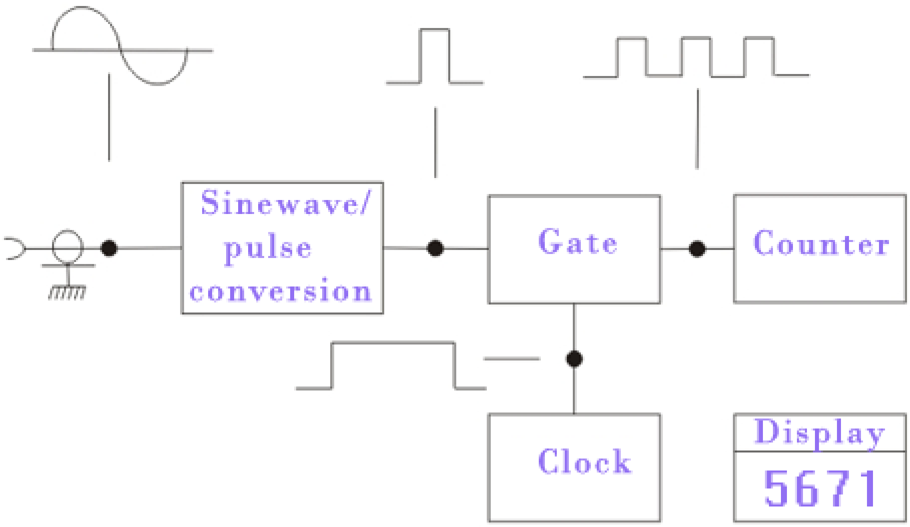
Digital frequency meter is a general purpose instrument that displays the frequency of a periodic electrical signal to an accuracy of three decimal places. It counts the number events occurring within the oscillations during a given interval of time. As the preset period gets completed, the value in the counter display on the screen and the counter reset to zero. Various types of instruments are available which operates at a fixed or variable frequency. But if we operate any frequency meter at different frequencies than the specified range, it could carry out abnormally. For measuring low frequencies, we usually use deflection type meters. The deflection of the pointer on the scale shows the change in frequency. The deflection type instruments are of two types: one is electrically resonant circuits, and other is ratio meter.



Operating Principle of Digital Frequency Meter

A frequency meter has a small device which converts the sinusoidal voltage of the frequency into a train of unidirectional pulses. The frequency of input signal is the displayed count, averaged over a suitable counting interval out of 0.1, 1.0, or 10 seconds. These three intervals repeat themselves sequentially. As the ring counting units reset, these pulses pass through the time-base-gate and then entered into the main gate, which opens for a certain interval. The time base gate prevents a divider pulse from opening the main gate during the display time interval. The main gate acts as a switch when the gate is open; pulses are allowed to pass. When the gate is closed, pulses are not allowed to pass that means the flow of pulses get obstructed.

The functioning of the gate is operated by the main-gate flip-flop. An electronic counter at the gate output that counts the number of pulses passed through the gate while it was open. As the main gate flip-flop receives next divider pulse, the counting interval ends, and divider pulses are locked out. The resultant value displayed on a display screen which has the ring counting units of scale-of-ten circuits and each unit couples to a numeric indicator, which provides the digital display. As the reset pulse generator is triggered, ring counters get reset automatically, and the same procedure starts again.



The range of modern digital frequency meter is between the range from 10^4 to 10^9 hertz. The possibility of relative measurement error ranges between from 10^{-9} to 10^{-11} hertz and a sensitivity of 10^{-2} volt.

Use of Digital Frequency Meter

- For testing radio equipment
- Measuring the temperature, pressure, and other physical values.
- Measuring vibration, strain
- Measuring transducers

✓ **Hydrometer**

A hydrometer is an instrument used to measure the specific gravity (or relative density) of liquids; that is, the ratio of the density of the liquid to the density of water.

A hydrometer is usually made of glass and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright. The liquid to be tested is poured into a tall container, often a graduated cylinder, and the hydrometer is gently lowered into the liquid until it floats freely. The point at which the surface of the liquid touches the stem of the hydrometer is noted. Hydrometers usually contain a scale inside the stem, so that the specific gravity can be read directly. A variety of scales exists, and is used depending on the context.

Hydrometers may be calibrated for different uses, such as a lactometer for measuring the density (creaminess) of milk, a saccharometer for measuring the density of sugar in a liquid, or an alcoholmeter for measuring higher levels of alcohol in spirits.

Principle

Operation of the hydrometer is based on Archimedes' principle that a solid suspended in a fluid will be buoyed up by a force equal to the weight of the fluid displaced by the submerged part of the suspended solid. Thus, the lower the density of the substance, the farther the hydrometer will sink

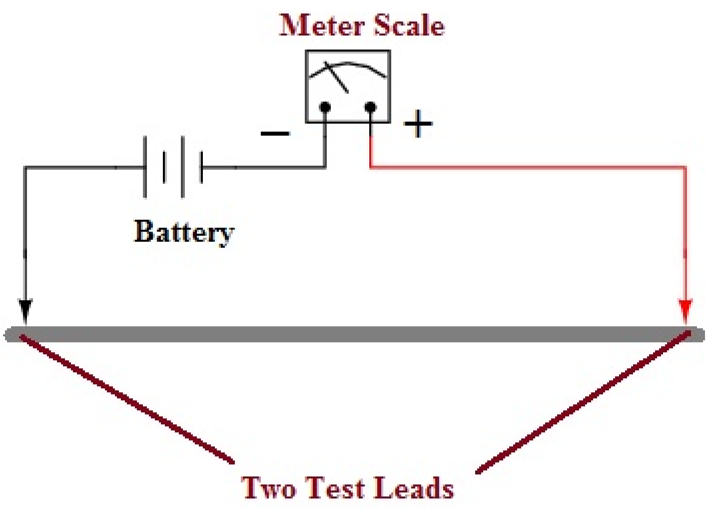
Content/Topic 2.Analogue and digital Instruments

- ✓ **Ammeter**

This type of device is used to measure the flow of current in amperes & displays the values of on a digital display. The designing of this device can be done by using a shunt resistor to generate a calibrated voltage that is proportional to the flow of current. These instruments provide information regarding the current draw & continuity in order to assist the consumer to troubleshoot variable loads & trends.

- ✓ **Ohmmeter**

The working principle of ohmmeter is, it comprises of a needle and two test leads. The needle deflection can be controlled with the battery current. Initially, the two test leads of the meter can be shorted together to calculate the resistance of an electrical circuit. Once the two leads of the meter are shorted, then the meter can be changed for appropriate action in a fixed range. The needle comes back to the highest point on the meter scale, and the current in the meter will be highest. An ohmmeter circuit diagram is shown below.



Once the testing of the circuit is done then the test leads of the meter must be detached. Once the two test leads of the meter are connected to the circuit then the battery gets discharged. When the test leads get shorted then the rheostat will be adjusted. The meter needle can be reached to the lowest position that is zero, and then there will be zero resistance among the two test leads.

- ✓ **Voltmeters**

Voltmeter is an electrical measuring instrument used to measure potential difference between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are available for the purpose of voltage measurement i.e. **analog and digital**. Analog voltmeters generally contain a dial with a needle moving over it according to the measure and hence displaying the value of the same. With time analog voltmeters are replaced by **digital voltmeters** due to the same advantages associated with digital systems. Although digital voltmeters do not fully replace analog voltmeters, still there are many places where analog voltmeters are preferred over digital voltmeters. Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

Advantages Associated with Digital Voltmeters

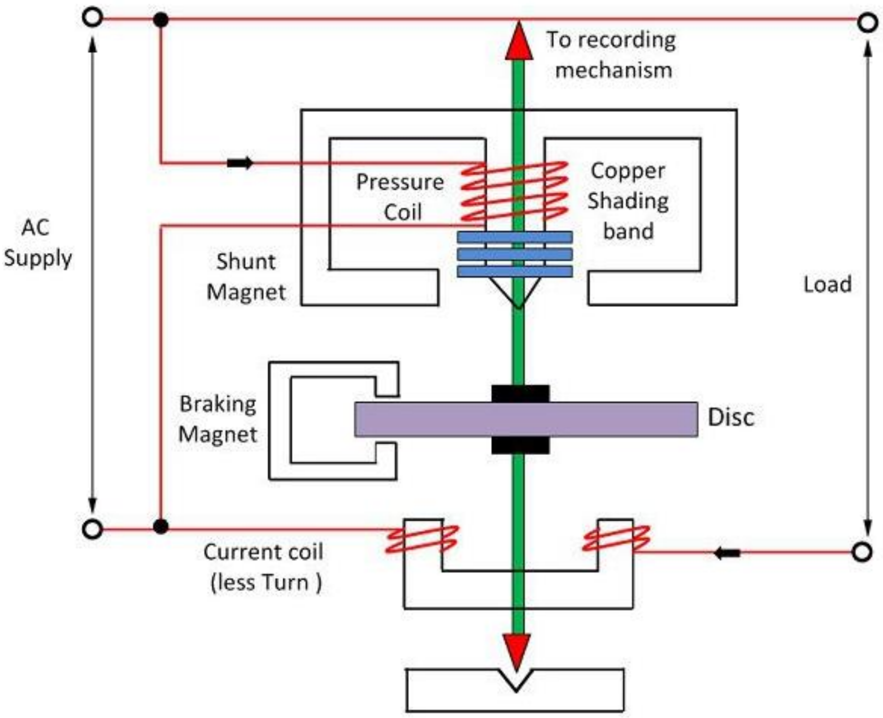
- ❖ Read out of DVMs is easy as it eliminates observational errors in measurement committed by operators.
- ❖ Error on account of parallax and approximation is entirely eliminated.
- ❖ Reading can be taken very fast.
- ❖ Output can be fed to memory devices for storage and future computations.
- ❖ Versatile and accurate
- ❖ Compact and cheap
- ❖ Low power requirements
- ❖ Portability increased

✓ **Wattmeter**

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer chip to determine watts. The computer can also perform statistics such as peak, average, low watts and kilowatt-hours consumed. They can monitor the power line for voltage surges and outages. In 2009, a variety of inexpensive digital wattmeters are available to consumers. With the falling price and improved capabilities of digital electronics, they have become popular for conveniently measuring power consumption in household appliances with an eye toward saving energy and money.

✓ **Energy meter**

The meter which is used for measuring the energy utilises by the electric load is known as the energy meter. The energy is the total power consumed and utilised by the load at a particular interval of time. It is used in domestic and industrial AC circuit for measuring the power consumption. The meter is less expensive and accurate. The construction of the single phase energy meter is shown in the figure below.



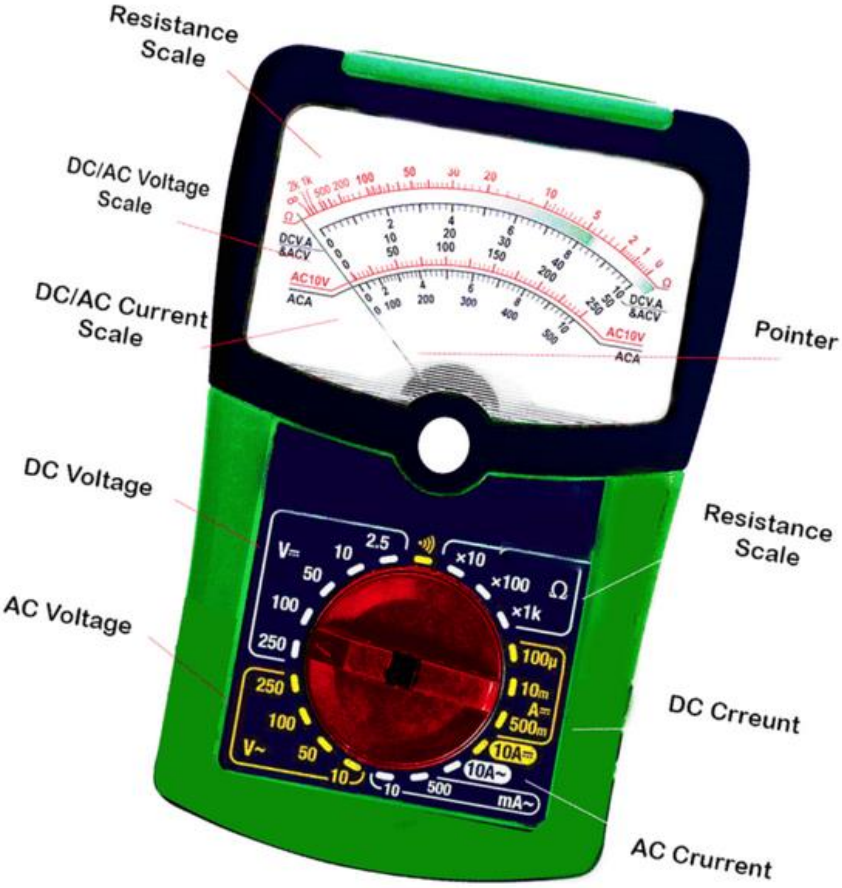
✓ **Multimeter**

A multimeter is a device used to measure two or more electrical quantities. A multimeter can be used to measure electrical functions such as voltage, current, resistance, continuity and some are able to measure electrical frequency.

Digital Multimeter

A digital multimeter (DMM) is a multifunctional meter that displays its electrical quantitative values on an LCD screen. A digital multimeter much like an analog meter, it is able to read voltage, current, and resistance. What makes a digital multimeter differ from the analog meter is its ability to display measured electrical values quickly without any computations. Because of its design, a processor can be built into the meter which allows the user to take measurements of frequency, the inductance of a coil, capacitance of a capacitor, and a host of other high functional electrical measurements. There two types of digital multimeters (DMM): scalable digital multimeter and auto-ranging digital multimeter as shown in Figure 1. When working with the scalable digital multimeter you need to have an idea of the value of voltage, current, or resistance that you are attempting to measure. Failure to observe these values will result in inaccurate readings and possible damage to the meter. The auto-ranging digital multimeter is more widely used due to its ease, high functionality, and quick display readings achieved without the user completing the calculations.

Analog Multimeter



Analog meters are a multifunctional multimeter that operates based on electrical mechanical movement. Analog meters use a printed linear or nonlinear background and a mechanical pointer. The pointer moves as a result of the flow of current through a built-in coil, the presence of electrical pressure, or the internal power source that is needed for resistance measurements. The advantage of an analog meter is relatively small; however, it allows you to see small changes in current flow and a change in voltage in real time. Analog meters require great mathematical skills because you are required to make quick calculations based on the printed scale. Time used while calculating mathematical solutions while taking a reading with an analog meter could be better used to resolve other problems.

- ✓ **Techniques for keeping and transportation of measuring instruments**
  - ❖ Store the instruments strictly separate from cutting or hand tools!
  - ❖ Transport the instruments exclusively in the covers or containers intended for this purpose!
  - ❖ Deposit the instruments during use on a piece of cloth or in special containers with padding!
  - ❖ Handle the instruments with care - avoid any damage by shocks or by dropping them!
  - ❖ Slightly grease the instruments after use with nonacid grease - protect them against rust!
  - ❖ Have the instruments checked every 6 to 12 months depending on the degree of accuracy!

Learning Outcome 2.3: Execute measurements

Content/Topic1. Accuracy and precision

Often the concepts accuracy and precision are used interchangeably; they are regarded as synonymous. These two terms, however, have an entirely different meaning. The accuracy indicates how close the measured value is from its actual value, i.e. the deviation between the measured and actual values. Precision refers to the random spread of the measured values.

When a number of measurements is done to a stable voltage or other parameter, the measured values will show a certain variation. This is caused by thermal noise in the measuring circuit of the measuring equipment and the measurement set-up. The left graph in Figure 1 shows these variations.

Accuracy and precision thus have a different meaning. It is therefore quite possible that a measurement is very precise but not accurate. Or conversely, a very accurate measurement, but not precise. In general, a measurement is considered valid if both the measurement is precise as well accurate.

- ✓ **Accuracy**

Accuracy is an indication of the correctness of a measurement. Because at a single measurement the precision affects also the accuracy, an average of a series of measurements will be taken.

The uncertainty of measuring instruments is usually given by two values: uncertainty of reading and uncertainty over the full scale. These two specifications together determine the total measurement uncertainty.

These values for the measurement uncertainty is specified in percent or in ppm (parts per million) relative to the current national standard. 1 % corresponds to 10000 ppm.

The specified uncertainty is quoted for specified temperature ranges and for certain time period after calibration. Please also note that at different ranges other uncertainties may apply.

- ✓ **Precision**

The term precision is used to express the random measurement error. The random nature of the deviations of the measured value is mostly of thermal origin. Because of the arbitrary nature of this noise it's not possible to give an absolute error. The precision gives only the probability that the measurement value is between given limits.

- ✓ **Improving precision**

The precision of a measurement can be improved by oversampling or filtering. The individual measurements are averaged out so that the noise quantity is greatly reduced. The spread of the measured values is hereby also reduced. With oversampling or filtering must be taken into account that this may reduce the bandwidth.

- ✓ **Resolution**

The resolution of a measurement system is the smallest yet to distinguish different in values. The specified resolution of an instrument has no relation to the accuracy of measurement.

Content/Topic 2. Calibration of the instrument

- QA Managers/Supervisors shall include procedures for calibration and/or performance verification of new equipment in Section technical procedures.
- Calibration procedures shall be appropriate for the intended use of the equipment and shall provide criteria for determining if calibration is satisfactory.
- Manufacturer operating manuals shall be consulted to determine the correct calibration interval. Equipment which requires calibration shall not be used if satisfactory calibration cannot be achieved or the calibration date has passed. Equipment used infrequently, such that the manufacturers' recommendations cannot be followed, shall have calibration verified prior to use. Prior to being used in testing, new equipment (or any piece of equipment which leaves the control of the Laboratory) shall undergo calibration procedures or performance verification.
- Calibration records shall be maintained and associated with the unique identifier of each piece of equipment. These records shall include:

  - The identity of the item of equipment and software.
  - Name of manufacturer.
  - Serial number or unique identifier.
  - Date of calibration.
  - Current location.
  - Manufacturer's instructions or a reference to location.
  - The reference standard certified reference material or reference material used for calibration.
  - Copies of all reports, results of calibration, and/or certificates of calibration.
  - A maintenance plan and due date for the next calibration.
  - The identity of the individual performing calibration.

- When external calibrations are performed, service providers that demonstrate competence, measurement capability, and traceability shall be used. Calibration certificates from these providers shall contain the measurement results, including the measurement uncertainty and/or a statement of compliance with an identified metrological specification. When possible, providers accredited to ISO 17025 shall be used. Copies of the provider's accreditation documentation shall be maintained by the Quality Manager (QM).

- If calibrations are performed by an outside vendor, the Section document control custodian shall maintain the original calibration records provided by the vendor and a copy of the relevant records shall be readily available.
- Laboratory equipment requiring calibration shall be labelled or coded to indicate the calibration status, including the date when last calibrated and the due date for recalibration (or expiration criteria for when recalibration is due).

Ontent/Topic 3. Recording of measurement

1. Immediately record the measurement after it is read. Call out the measurement * continuously until you have recorded the measurement. It helps to have your pen or pencil and collection sheet near you.

2. Record the measurement directly onto the data collection sheet. The more times the measurement is copied, the more chances of error there are.

3. Record measurements clearly and neatly, the same way every time. Check to make sure it is accurate and legible.

Unit of measurement

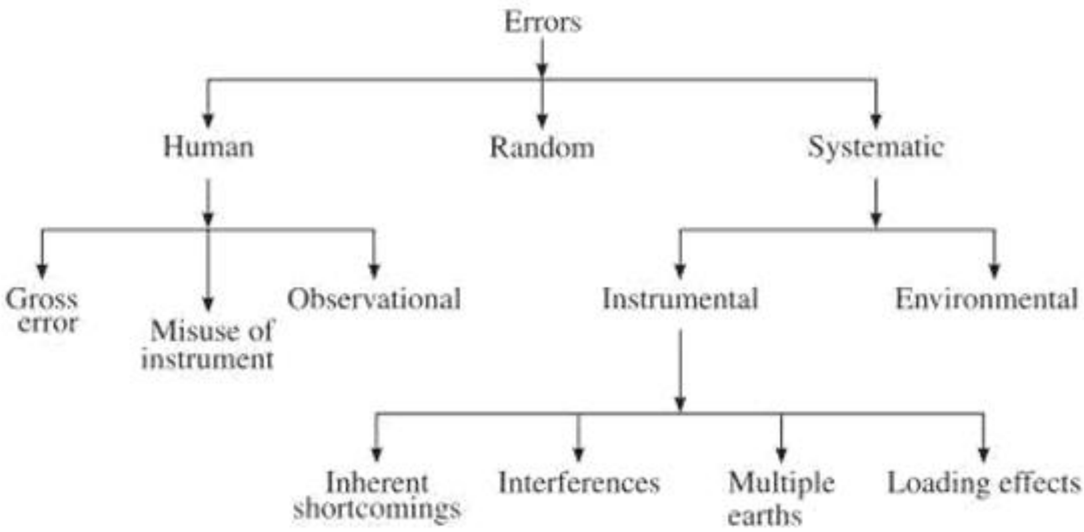
A unit of measurement is a definite magnitude of a quantity, defined and adopted by convention or by law that is used as a standard for measurement of the same kind of quantity. Any other quantity of that kind can be expressed as a multiple of the unit of measurement. For example, a length is a physical quantity. The metre is a unit of length that represents a definite predetermined length. When we say 10 meters (or 10 m), we actually mean 10 times the definite predetermined length called "metre". Measurement is a process of determining how large or small a physical quantity is as compared to a basic reference quantity of the same kind.

The definition, agreement, and practical use of units of measurement have played a crucial role in human endeavour from early ages up to the present. A multitude of systems of units used to be very common. Now there is a global standard, the International System of Units (SI), the modern form of the metric system.

Content/Topic 4. Classification of Errors

Generally errors are classified into three types: systematic errors, random errors and blunders.

1) Gross Errors
2) Blunders
3) Measurement Errors



1.1 Gross Errors

Gross errors are caused by mistake in using instruments or meters, calculating measurement and recording data results. The best example of these errors is a person or operator reading pressure gage 1.01N/m2 as 1.10N/m2. It may be due to the person's bad habit of not properly remembering data at the time of taking down reading, writing and calculating, and then presenting the wrong data at a later time. This may be the reason for gross errors in the reported data, and such errors may end up in calculation of the final results, thus deviating results.

1.2 Blunders

Blunders are final source of errors and these errors are caused by faulty recording or due to a wrong value while recording a measurement, or misreading a scale or forgetting a digit while reading a scale. These blunders should stick out like sore thumbs if one person checks the work of another person. It should not be comprised in the analysis of data.

1.3 Measurement Error

The measurement error is the result of the variation of a measurement of the true value. Usually, Measurement error consists of a random error and systematic error. The best example of the measurement error is, if electronic scales are loaded with 1kg standard weight and the reading is 10002grams, then the measurement error is = (1002grams-1000grams) =2grams

Measurement Errors are classified into two types: systematic error and random errors

1.4 Systematic Errors

The Systematic errors that occur due to fault in the measuring device are known as systematic errors. Usually they are called as Zero Error – a positive or negative error. These errors can be detached by correcting the measurement device. These errors may be classified into different categories. In order to understand the concept of systematic errors, let us classify the errors as:

- ✓ Instrumental Errors
- ✓ Environmental Errors
- ✓ Observational Errors
- ✓ Theoretical

1. **Instrumental Errors**

Instrumental errors occur due to wrong construction of the measuring instruments. These errors may occur due to hysteresis or friction. These types of errors include loading effect and misuse of the instruments. In order to reduce the gross errors in measurement, different correction factors must be applied and in the extreme condition instrument must be recalibrated carefully.

2. Environmental Errors

The environmental errors occur due to some external conditions of the instrument. External conditions mainly include pressure, temperature, humidity or due to magnetic fields. In order to reduce the environmental errors

- ✓ Try to maintain the humidity and temperature constant in the laboratory by making some arrangements.
- ✓ Ensure that there shall not be any external electrostatic or magnetic field around the instrument.

3. Observational Errors

As the name suggests, these types of errors occurs due to wrong observations or reading in the instruments particularly in case of energy meter reading. The wrong observations may be due to PARALLAX. In order to reduce the PARALLAX error highly accurate meters are needed: meters provided with mirror scales.

4. **Theoretical Errors**

Theoretical errors are caused by simplification of the model system. For example, a theory states that the temperature of the system surrounding will not change the readings taken when it actually does, then this factor will begin a source of error in measurement.

5. Random Errors

Random errors are caused by the sudden change in experimental conditions and noise and tiredness in the working persons. These errors are either positive or negative. An example of the random errors is during changes in humidity, unexpected change in temperature and fluctuation in voltage. These errors may be reduced by taking the average of a large number of readings.

Content/Topic 5.Types of errors in measurement

The measurement of an amount is based on some international standards which are completely accurate compared with others. Generally, measurement of any quantity is done by comparing it with derived standards with which they are not completely accurate. Thus, the errors in measurement are not only due to error in methods, but are also due to derivation being not done perfectly well. So, 100% measurement error is not possible with any methods.

It is very important for the operator to take proper care of the experiment while performing on industrial instruments so that the error in measurement can be reduced. Some of the errors are constant in nature due to the unknown reasons, some will be random in nature, and the other will be due to gross blunder on the part of the experimenter.

- ✓ **Errors in Measurement System**

An error may be defined as the difference between the measured value and the actual value. For example, if the two operators use the same device or instrument for finding the errors in measurement, it is not necessary that they may get the similar results. There may be a difference between both measurements. The difference that occurs between both the measurements is referred to as an ERROR.

Sequentially, to understand the concept of errors in measurement, you should know the two terms that define the error. They are true value and measured value. The true value is impossible to find out the truth of quantity by experimental means. It may be defined as the average value of an infinite number of measured values. Measured value can be defined as the estimated value of true value that can be found by taking several measured values during an experiment.

- **Absolute**

Absolute error is the magnitude of the difference between the exact value and the approximation. Given an approximation of a correct value x, we define the absolute value of the difference between the two values to be the absolute error. We will represent the absolute error by **Eabs**, therefore; it is often sufficient to record only two decimal digits of the absolute error. Thus, it is sufficient to state that the absolute error of the approximation 3.55 to the correct value 3.538385 is 0.012. There are two problems with using the absolute error:

- **Significance**

It gives you a feeling of the size of the error but how significant is the error? If the absolute error was 3.52, is this significant? If the correct value is x = 5030235.23, then probably not, however if the correct value is x = 5.03023523, then an absolute error 3.52 is probably very significant.

- ✓ **Units**

The absolute error will change depending on the units used. The absolute error of the approximation 2.4 MV of an actual voltage of 2.573243 MV is 0.17 MV, whereas the absolute error of the approximation 2400000 V to an actual voltage of 2573243 V is 170000 V.

- ✓ **Relative, percentage**

To solve the problems of significance and units, we may compare the absolute error relative to the correct value. Thus, we define the relative error to be the ratio between the absolute error and the absolute value of the correct value and denote it by **Erel.**

In this equation, any units cancel, so the relative errors of the approximations 2.4 MV and 2400000 V versus the actual voltages of 2.573243 MV and 2573243 V, respectively, are equal. Also, a relative error of 0.01 means that the approximation is correct to within one part in one hundred, regardless of the size of the actual value. Whether this is sufficiently accurate depends on the requirements.

In this class, we will usually use the relative error, though if we are only trying to show that a sequence of errors is decreasing to zero, we may use the absolute error (if a sequence of absolute errors is going to zero, then the relative errors will go to zero, too). One problem with using the relative error is when the correct value is zero (0), but this seldom appears in real-life situations. On occasion, the relative error by 100 and refer to as the percent relative error.

Learning unit 3: Clean tools and equipment

LO 3.1: Clean tools and equipment

Content/Topic 1.The purposes of cleaning tools and equipment

You can have all the good intentions in the world, training your people to clean effectively and investing in the proper tools but if you don't store your equipment the right way, you're sabotaging the entire process. Maintaining cleaning equipment is important because if your tools are stored incorrectly, the bacteria you're trying to eliminate will grow right on or in them. Kaivac cleaning systems are designed to clean more dirt and bacteria from surfaces than traditional methods, but you won't get the results you need from any tools unless you care for them the right way. Most tool maintenance just requires common sense, but there are some practices you may not have thought about.

General Habits

Develop a tool storage system and instill its importance into your workers. Make cleaning and storing the tools a part of your entire cleaning system. Some rules aren't defined by the type of tool your employee is using and can be applied to anything they need on shift:

- ❖ Clean and store the equipment correctly after every use.

- ❖ Remove any liquids that may have been contaminated.
- ❖ Never put equipment away unless it's ready for the next day's use.

Content/Topic 2. Methods of cleaning tools and equipment

Despite the amount of soap and cleaning agents used on cleaning tools, they still need to be cleaned on their own and properly taken care of to ensure food safety and quality. Even if it seems like a brush that stays inside a soapy bucket all day should be clean, contaminants and microbes can still build up without the right maintenance.

Proper cleaning and maintenance begins with employee training and supervision and should be considered a significant part of the facility’s overall hygiene and sanitation plan.

The cleaning regime of different tools is influenced by their purpose or use. Different cleaning routines should be established for food contact and non-food contact tools. For example, a broom used in a low-risk environment probably won’t be cleaned after every use. However, a tank brush that’s used for cleaning the interior of a batch tank should be cleaned and sanitized before and after each use. To avoid cross-contamination, tools used on food contact surfaces must be easily identifiable and kept separate from those used on non-food contact surfaces. Color coding is often a simple solution for achieving this level of intended segregation.

To ensure tools have a longer utility and lifespan, they must be properly cared for. Cleaning your tools should be approached in the same manner that you clean any other equipment or surface in your facility.

The cleaning principles are:

1. **Dry clean.** Remove visible and gross soils and debris.
2. **Pre-rinse.** Rinse all areas and surfaces until they are visibly free of soil.
3. **Wash (soap and scrub).** Use the right detergent in the right concentration with the right level of mechanical action in the right water temperature for the right contact time.
4. **Post-rinse.** Rinse away all visible detergents and remaining soil.
5. **Inspect.** Look again at crevices and other contamination traps to ensure they’re free of soils and detergents. Determine whether steps 1-4 should be performed again.
6. **Sanitize.** Foam, wipe or spray sanitizing chemicals onto surfaces as per the appropriate instructions.
7. **Dry.** Ensure adequate time is allotted for equipment to thoroughly dry.
8. **Verification.** Gather proof that the cleaning performed achieved the expected level by following facility verification protocols.

LO 3. 2: Clean the working area

Content/Topic1. Arrangement of non-used materials

Older pieces of equipment and tools may not contain features that reduce or eliminate the potential for accidental exposure and injury to the user. After five years, most equipment requires expensive maintenance to operate; and after 10 years, most equipment is obsolete and parts are hard to find. Planning for maintenance costs and eventual replacement costs for critical equipment and specialty facility infrastructure is another way to ensure safety during research operations.

- **Laboratory Equipment Owner Decommissioning**

The Laboratory Equipment Owner Decontamination Form indicates to personnel servicing or moving your equipment that the equipment has been cleaned and is free of contamination. If the equipment is not a biological safety cabinet or has not been exposed to radioactive material, then complete the form, sign it, and attach it to the equipment.

If the equipment is a biological safety cabinet or has been exposed to radioactive material, you will be required to complete the appropriate sections of the form and obtain authorization or clearance before the equipment can be serviced or moved.

Content/Topic2. Removal of waste material

Waste management is the collection, transport, processing or disposal of waste materials, usually ones produced by human activity, in an effort to reduce their effect on human health or local amenity. A sub-focus in recent decades has been to reduce waste materials' effect on the environment and to recover resources from them.

Waste management can involve solid, liquid or gaseous wastes, with different methods and fields of expertise for each.

Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential industrial, and commercial producers. Waste management for non-hazardous residential and institutional waste in metropolitan areas is usually the responsibility of Government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

Content/topic 3. Methods of cleaning workplace area

Many cleaning and degreasing substances used are harmful if not used properly, either through direct skin contact or through breathing in mist or vapour given off, commonly causing dermatitis and narcotic effects. Some cleaners give off vapour which is easily ignited.

To minimize hazards:

- ✓ Compare manufacturers data sheets and use the least harmful
- ✓ Read safety data sheets
- ✓ Avoid spills and evaporation by keeping lids on containers
- ✓ Mark contents clearly
- ✓ Wear appropriate protective equipment such as gloves, overalls, eye and foot protection to prevent contact with fluids.

When using liquids:

- ✓ Work in well ventilated areas and avoid working in confined spaces
- ✓ Where necessary to work in a confined space special precautions are necessary and a risk assessment required

Vapour degreasing tanks

Using these badly may cause exposure to harmful levels of vapour which if inhaled may cause drowsiness or in extreme cases unconsciousness. Direct contact may cause irritation and dermatitis and should never be frequent or prolonged.

To minimise exposure:

- ✓ Position tanks in an area free from draughts
- ✓ Stack components inside container so that they drain properly
- ✓ Allow them to dry before removing them
- ✓ Use covers when not using tank

Metal working Fluids

Ill health from metal working fluids, used neat or mixed with water, most commonly arises from:

a) Skin contact during

- ✓ Preparation, application and removal of fluid
- ✓ Handling of workpieces

- ✓ Splashing and machining
- ✓ Changing and setting of tools
- ✓ Maintenance and cleaning of machines

a) Breathing in aerosols, mist and fumes when machining causing irritation of the eyes, nose and throat and occasionally breathing difficulties.

To minimize hazards:

DO

- ✓ Read and follow manufacturers guidance
- ✓ Top up in accordance with suppliers instructions
- ✓ Keep machines clean and free from debris
- ✓ Clean sumps, pipe work and machines before refilling with fluids which should be mixed outside of the machine
- ✓ Wash with soap and water regularly to remove metalworking fluids
- ✓ Keep oily rags out of pockets

DON'T

- ✓ Wear jewellery, rings or watch straps under which fluids may collect
- ✓ Use unrefined mineral oils and mildly refined distilled oils which may cause cancer and for which safer alternatives are available.
- ✓ Use fluids beyond their normal life
- ✓ Allow other oils to contaminate the metalworking fluid
- ✓ Allow fluids to overheat
- ✓ Allow water-mix fluids to stagnate when not in use
- ✓ Eat or drink in working areas

Learning Outcome 3.3: Manage waste materials

Content/Topic 1.Selection of area for storing waste materials

Managing domestic, industrial and commercial waste has traditionally consisted of collection, followed by disposal. Depending upon the type of waste and the area, a level of processing may follow collection. This processing may be to reduce the hazard of the waste, recover material for recycling, produce energy from the waste, or reduce it in volume for more efficient disposal.

Collection methods vary widely between different countries and regions, and it would be impossible to describe them all. For example, in Australia most urban domestic households have a 240-litre bin that is emptied weekly by the local Council. Many areas, especially those in less developed areas, do not have a formal waste-collection system in place.

Disposal methods also vary widely. In Australia, the most common method of disposal of solid waste is to landfills, because it is a large country with a low-density population. By contrast, in Japan it is more common for waste to be incinerated, because the country is smaller and land is scarce.

- **Landfill**

Disposing of waste in a landfill is the most traditional method of waste disposal, and it remains a common practice in most countries. Historically, landfills were often established in disused quarries or mining voids. A well-run landfill can be a hygienic and relatively inexpensive method of disposing of waste materials.

Older or poorly managed landfills can create number of adverse environmental impacts, including wind-blown litter, attraction of vermin and soluble contaminants (leachate) leaching into and polluting groundwater. Another product of landfills containing putrescible wastes is landfill gas (mostly composed of methane and carbon dioxide), which is produced as the waste breaks down.

Characteristics of a modern, well-run landfill should include methods to contain leachate, such as clay or plastic liners. Disposed waste should be compacted and covered to prevent vermin and wind-blown litter. Many landfills also have a landfill gas extraction system installed after they are closed to extract the gas generated by the decomposing waste materials. This gas is often burnt to generate power. Generally, even flaring the gas off is a better environmental outcome than allowing it to escape to the atmosphere, as this consumes the methane (a far more potent greenhouse gas than carbon dioxide).

Many local authorities (especially in urban areas) have found it difficult to establish new landfills, due to opposition from adjacent landowners. Few people want a landfill in their local neighborhood. As a result, solid waste disposal in these areas has become more expensive as material must be transported further away for disposal.

Some oppose the use of landfills in any way, anywhere, arguing that the logical end result of landfill operations is that it will eventually leave a drastically polluted planet with no canyons, and no wild space. Some futurists have stated that landfills will be the "mines of the future": as some resources become scarcer, they will become valuable enough that it would be necessary to 'mine' them from landfills where these materials were previously discarded as valueless.

This fact, as well as growing concern about the impacts of excessive materials consumption, has given rise to efforts to minimise the amount of waste sent to landfill in many areas. These efforts include taxing or levying waste sent to landfill, recycling the materials, converting material to energy, designing products that require less material, etc. A related subject is that of industrial ecology, where the material flows between industries is studied. The by-products of one industry may be a useful commodity to another, leading to reduced waste materials.

- **Incineration**

Incineration is the process of destroying waste material by burning it. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is recognised as a practical method of disposing of hazardous waste materials (such as biological medical waste).

Though still widely used in many areas (especially developing countries), incineration as a waste management tool is becoming controversial for several reasons.

First, it may be a poor use of many waste materials because it destroys not only the raw material, but also all of the energy, water, and other natural resources used to produce it. Some energy can be reclaimed as electricity by using the combustion to create steam to drive an electrical generator, but even the best incinerator can only recover a fraction of the caloric value of fuel materials.

Second, incineration creates toxic gas and ash, which can harm local populations and pollute groundwater. Modern, well-run incinerators take elaborate measures to reduce the amount of toxic products released in exhaust gas. But concern has increased in recent years about the levels of dioxins that are released when burning mixed waste.

Until recently, safe disposal of incinerator waste was a major problem. In the mid-1990s, experiments in France and Germany used electric Plasma torches to melt incinerator waste into inert glassy pebbles, valuable in concrete production. Incinerator ash has also been chemically separated into lye and other useful chemicals.

Content/Topic 2. Keeping waste materials according to their nature

A relatively recent idea in waste management has been to treat the waste material as a resource to be exploited, instead of simply a challenge to be managed and disposed of. There are a number of different methods by which resources may be extracted from waste: the materials may be extracted and recycled, or the calorific content of the waste may be converted to electricity.

The process of extracting resources or value from waste is variously referred to as secondary resource recovery, recycling, and other terms. The practice of treating waste materials as a resource is becoming more common, especially in metropolitan areas where space for new landfills is becoming scarcer. There is also a growing acknowledgement that simply disposing of waste materials is unsustainable in the long term, as there is a finite supply of most raw materials. There are a number of methods of recovering resources from waste materials, with new technologies and methods being developed continuously.

Content/Topic 3. Maintain waste bin

Recycling means to reuse a material that would otherwise be considered waste. The popular meaning of recycling 'in most developed countries has come to refer to the widespread collection and reuse of single-use beverage containers. These containers are collected and sorted into common groups, so that the raw materials of the items can be used again (recycled).

In developed countries, the most common consumer items recycled include aluminum beverage cans, steel food and aerosol cans, HDPE and PET plastic bottles, glass bottles and jars, paperboard cartons, newspapers, magazines, and cardboard. Other types of plastic (e.g PVC) are also recyclable, although not as commonly collected. These items are usually composed of a single type of material, making them relatively easy to recycle into new products. The recycling of obsolete computers and electronic equipment is important although more costly due to the separation and extraction problems. The recycling of junked automobiles also depends on the scrap Metal market.

Recycled or used materials have to compete in the marketplace with new (virgin) materials. The cost of collecting and sorting the materials usually means that they are equally or more expensive than virgin materials. This is most often the case in developed countries where industries producing the raw materials are well-established. Practices such as trash picking can reduce this value further, as choice items are removed (such as aluminium cans). In some countries, recycling programs are subsidised by deposits paid on beverage

Not accounted for by most economic systems are the benefits to the environment of recycling these materials, compared with extracting virgin materials. It usually requires significantly less energy, water and other resources to recycle materials than to produce new materials. For example, recycling 1000 kg of aluminium cans saves approximately 5000 kg of bauxite ore being mined and 95% of the energy required to refine it (source: ALCOA Australia).

In many areas, material for recycling is collected separately from general waste, with dedicated bins and collection vehicles. Other waste management processes recover these materials from general waste streams. This usually results in greater levels of recovery than separate collections of consumer-separated beverage containers, but are more complex and expensive.

- **Composting and Digestion**

Waste materials that are organic in nature, such as food scraps and paper products, are increasingly being recycled. These materials are put through a composting or artificial digestion process to decompose the organic matter and kill pathogens. The organic material is then recycled as compost for agricultural or landscaping purposes.

There are a large variety of composting methods and technologies, varying in complexity from simple window composting of shredded plant material, to automated enclosed-vessel digestion of mixed domestic waste. Composting methods can be broadly categorized into aerobic or anaerobic methods, although hybrids of the two methods also exist.

Aerobic (meaning ‗requiring air') methods of composting seek to aerate the organic material continuously or frequently, in order to promote rapid and odorless decomposition. Anaerobic (‗not requiring air') methods of composting seek to maximize the generation of gases such as methane during the process, in order to produce power from the waste materials.

- **Incineration, Pyrolysis and Gasification**

Use of incinerators for waste management is controversial, and most Americans passionately oppose it. This controversy roots from the understandable conflict between short-term concerns and long-term ones, in this case between burning the wastes now, or postponing this problem by passing the waste burden to future generations. Whether any form of incineration or thermal treatment should be defined as "resource recovery" is a matter of dispute in policy-making circles.

Pyrolysis and Gasification are two related forms of thermal treatment where materials are incinerated with limited oxygen. The process typically occurs in a sealed vessel, under high temperature and pressure. Converting material to energy this way is more efficient than direct incineration, with more energy able to be recovered and used.

Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid oil and gas can be burnt to produce energy or refined into other products. The solid residue (char) can be further refined into products such as activated Carbon.

Gasification used to convert organic materials directly into a synthetic gas composed of Carbon Monoxide and Hydrogen. The gas is then burnt to produce electricity and steam. Gasification is used in biomass power stations to produce renewable energy and heat.

Reference(s):

1. Principles of Power Systems: Rohit Mehta & V. K. Metha (Latest Edition)
2. Power System Analysis: Weedy $ Cory (Latest Edition)
3. Principles of power system, V.K MEHTA, ROHIT MEHTA, S.CHAND &COMPANY, NEW DELHI 2004
4. https://www.en.wikipedia.org/wiki/Personal_protective_equipment 31 August 2020
5. http://oursesonline.iasri.res.in/mod/resource/view.php?id=3563 1st September 2020
6. https://www.electricaltechnology.org/.../types-of-wiring-systems-electrical- wiring-methods.html
7. https://en.wikipedia.org/wiki/Measuring_instrumen on 2nd September 2020
8. https://www.electrical4u.com/principle-of-dc-generator on 2nd September 2020
9. https://sustainabledevelopment.un.org/content/documents
10. https://en.wikipedia.org/.../List_of_electrical_and_electronic_measuring_ equipment
11.https://www.researchgate.net/publication/286714704_Methods_for_Selection_of_Measuring_Instruments
12. http://www.egyankosh.ac.in/bitstream/123456789/35744/5/Unit-6.pdf
13.https://www.isoconsultantkuwait.com/2019/01/23/procedure-for-equipment-calibration-and-maintenance/