MEASUREMENT DEVICES

JABATAN KEJURUTERAAN ELEKTRIK

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Our hopes are, may this e-book helps students out there, especially engineering students in polytechnic, ease them to understand and improve them in measuring all electrical devices during practical session especially. Nevertheless, we also need any comment from reader to help us improve our next debut.

TABLE OF CONTENTS

01. MEASUREMENT AND ERROR

DEFINITION OF THE MEASUREMENT PROCESS

The process of determining the amount, degree, or capacity by comparison (direct or indirect) with the accepted standards of the system units being used. (Electronic measurement, H.s Kalsi)

THE MEASUREMENT PROCESS

In other word measurement an estimation of a physical parameter (quantity) by a measurement device (instrument).

Input Signal (Physical Parameter

Measurement Instrument (Measurement System)

Output Signal (Electrical Parameter)

Figure 1.1: Basic measurement process

ELEMENT IN MEASUREMENT SYSTEM

1

PRIMARY SENSING ELEMENT OR TRANSDUCER/ SENSOR

Sense and converts the input signal to a more convenient and practicable form (example: electrical signal)

2

VARIABLE MANIPULATION ELEMENT

process the transducer signal (electrical signal) to make it suitable for application to data presentation element

3

DATA PRESENTATION ELEMENT

an indication of the value of the measurement (readout device/display recording etc).

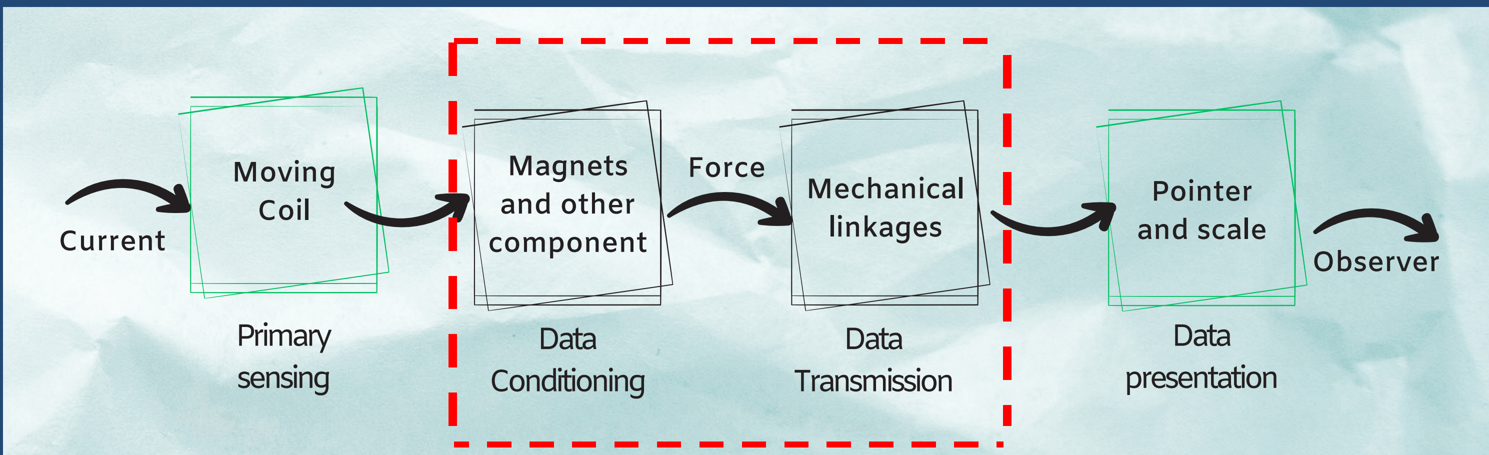


Figure 1.2 Variable Manipulation

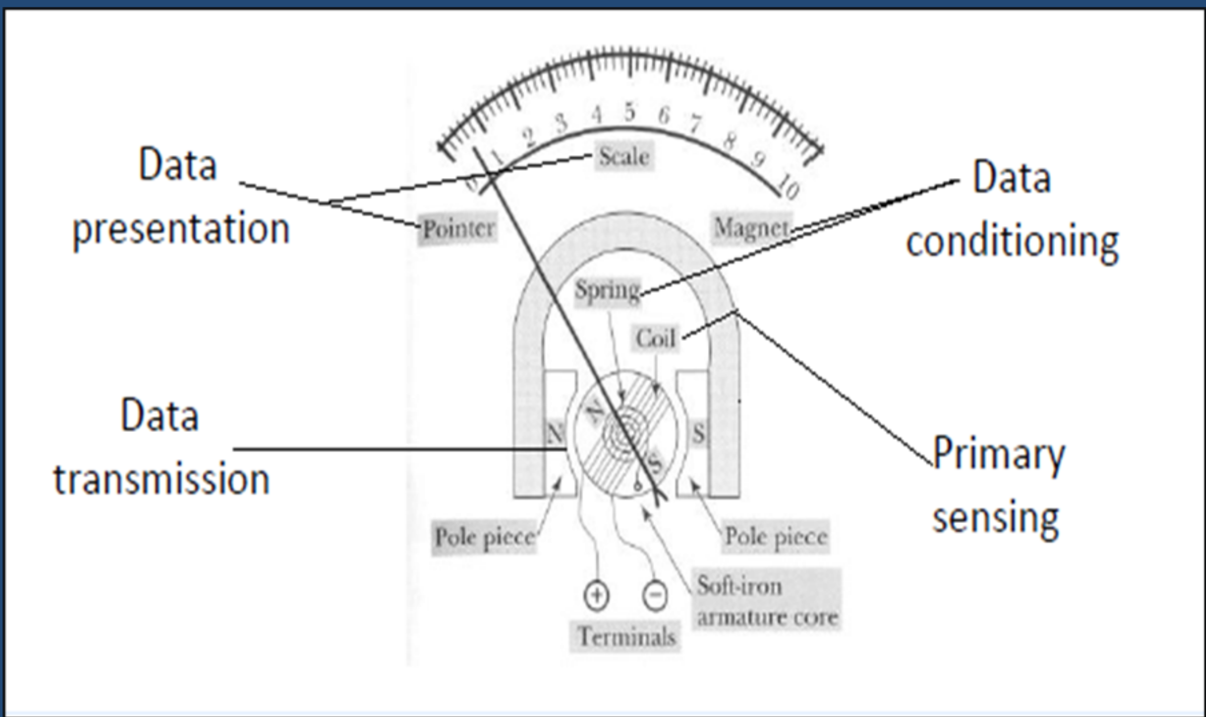
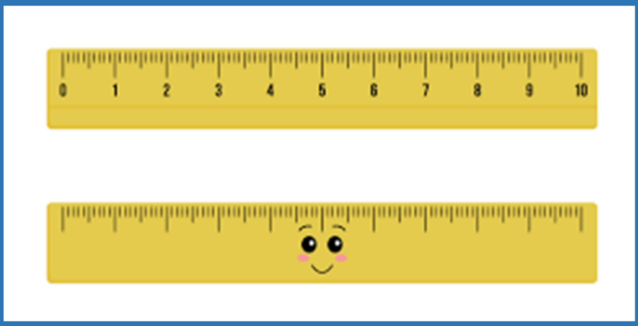


Figure 1.3 Ammeter Block Diagram

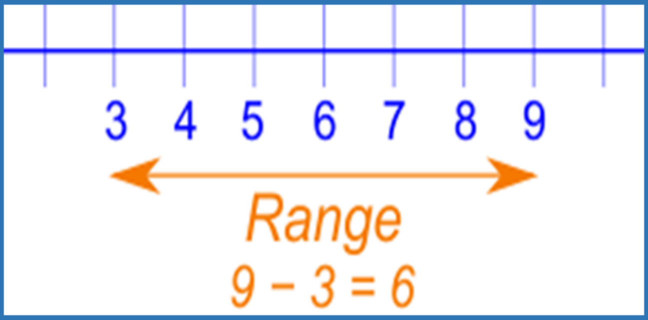
MEASUREMENT TERMINOLOGIES

SCALE



- A series of marks at regular intervals on an instrument that is used for measuring.
- The scale is depending on the range.

RANGE



- The minimum and maximum values of a quantity for which an instrument is designed to measure is called its range .
- E.g ammeter range : 0mA to 5 mA

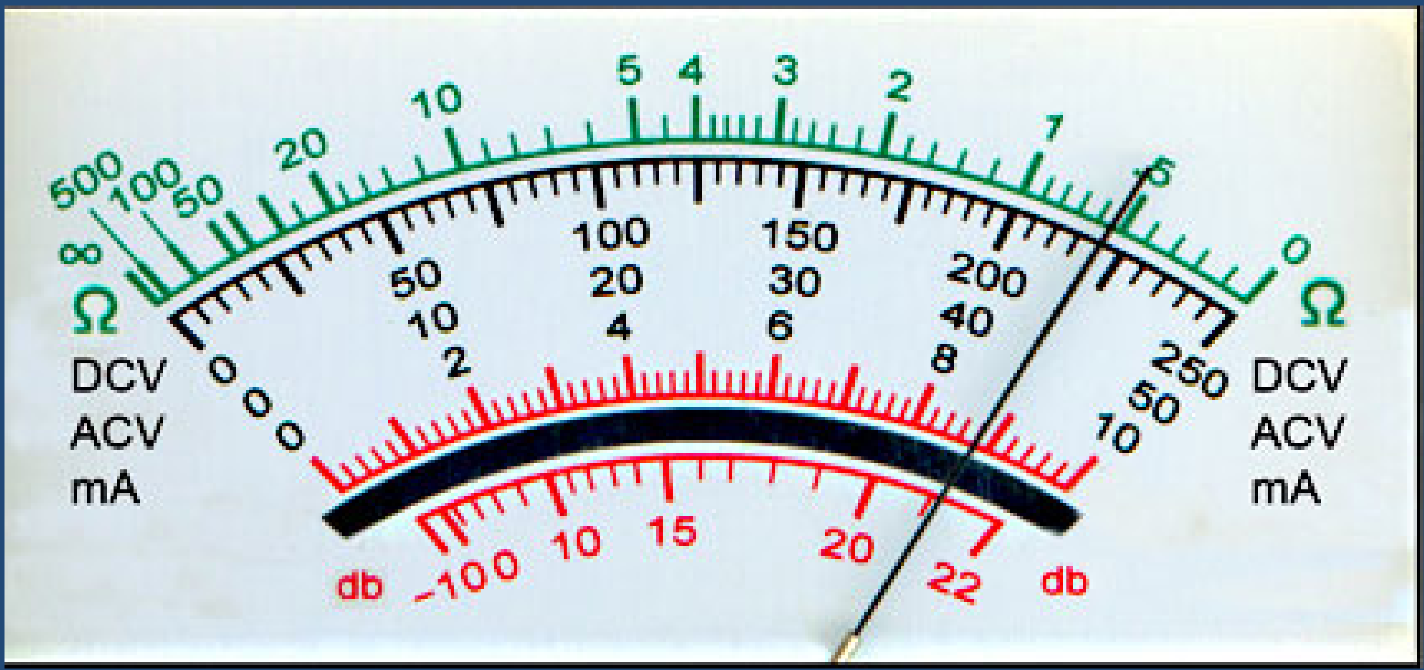


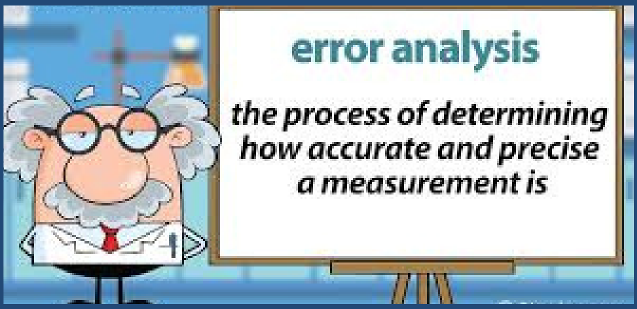
Figure 1.4 Scale Panel

ERROR IN MEASUREMENT

Definition of error :
The deviation/ different between true values (computed) and measured values of quantities

Factors that affect the measurements are related to :

- the measuring instruments
- the person using the instrument



Error may be expressed either as absolute or as percentage relative error

TYPES OF ERROR

GROSS ERROR

- Fault of person using the instruments such as incorrect reading , incorrect recording of data or incorrect use of instruments.
- Can be reduced : by proper meter reading and connection, avoid careless etc.

RANDOM ERROR

- These are errors that remain after gross and systematic errors have been substantially reduced. These errors are due to unknown causes.
- Can be minimized (reduced) by taking many reading of each instrument and analyzed statistically (determining mean value).

TYPES OF ERROR

SYSTEMATIC ERROR

Systematic Error Due to problems with instruments, environmental effects, or observational error

a) **Instrument errors** may be due to friction in bearing of the meter, incorrect spring tension, improper calibration or faulty instruments.

b) **Environmental errors** is Environmental conditions in which instruments are used may cause errors (Example : high temperature/ pressure / humidity/strong electrostatic or electromagnetic field.

c) **Observable errors** are those errors introduced by the observer. Probably the parallax error in reading a meter scale and the error of estimation. Can be reduced : proper maintenance, use and handling of instruments and minimized those effect magnetic shield

ABSOLUTE ERROR

Absolute Error Absolute (actual) error is the differences between the expected value and the measured value , or $e=|Y_n-X_n|$

where, e = absolute error

Y_n = Expected value

X_n = Measured value

5. Relative Error

Relative error is how much error you had compared to the real measurement

$$Relative\ Error = \frac{Absolute}{Expected\ Value}$$

$$= \left|\frac{Y_n - X_n}{Y_n}\right|$$

$$= \left|\frac{e}{Y_n}\right|$$

$$\%\ Error = \left|\frac{e}{Y_n}\right| \times 100$$

EXAMPLE

Question:

The measured value of a resistance is 10.25Ω, where as its value is 10.22Ω. Determine the absolute error of measurement.

Solution:

Given :

Measured value, X_n =10.25Ω

True value , Y_n =10.22Ω

Absolute error $e = |Y_n - X_n|$

= | 10.22 Ω -10.25 Ω |

= 0.03 Ω

CHARACTERISTIC OF MEASUREMENT

Figure 1.5 Accuracy and Precision

1. Accuracy

how close to indicating to the actual value.

$$Relative\ Accuracy, A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right|$$

$$\%\ Relative\ Accuracy, a = 100\% - \%\ e$$
$$= A \times 100\%$$

2. Precision

is a measure of the consistency or repeatability of measurements

3. Resolution

The smallest change in a measured variable to which an instrument will respond. It is very near to sensitivity

4. Significant Figure

A number are those digits that carry meaning contributing to its precision .

Example : 68Ω, 69Ω - two significant figures.

68.0Ω, 67.9Ω - three significant figures

STANDARD USED IN MEASUREMENT

1. International Standards

- Define by international agreement.
- They represent certain units of measurement to the closest possibly accuracy that production and measurement technology allow.
- Maintained at the international Bureau of Weight and Measures in Paris
- Example BSI(British Standard Institution), IEC(international Electro technical commission) and ISO (International Organization for Standard)

Base Quantity	Unit	Symbol
Length	meter	M
Mass	kilogram	Kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

TABLE 1.1 SI BASE UNIT

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

TABLE 1.2 SI PREFIXES

b. The Primary standards

- Maintained at national standard laboratories in different countries.
- Not available for use outside the national laboratories.
- Function - calibration and verification of secondary standards.
- EXAMPLE : SI : KG, POUND. (L , GELEN)

C. Secondary standards

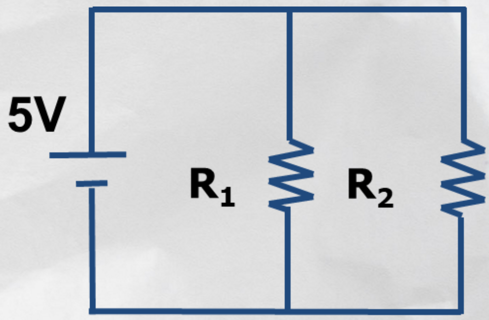
- It is basic reference standards used in industrial measurement laboratories.
- Each industry has its own secondary standard. Example: SIRIM, Timbang & Sukat kem. Perdagangan & perindustrian, Pusat penyelidikan pertahanan, local universiti and industries

d. Working standards

- The principle tools of a measurements laboratory.
- They are used to check and calibrate the instruments used in laboratory or to make comparison measurements in industrial application.
- Example : Instrumentation laboratory (The resistor manufacturing industry maintains a standard resistor in the laboratory for checking the values of the manufactured resistors)

TUTORIAL 1

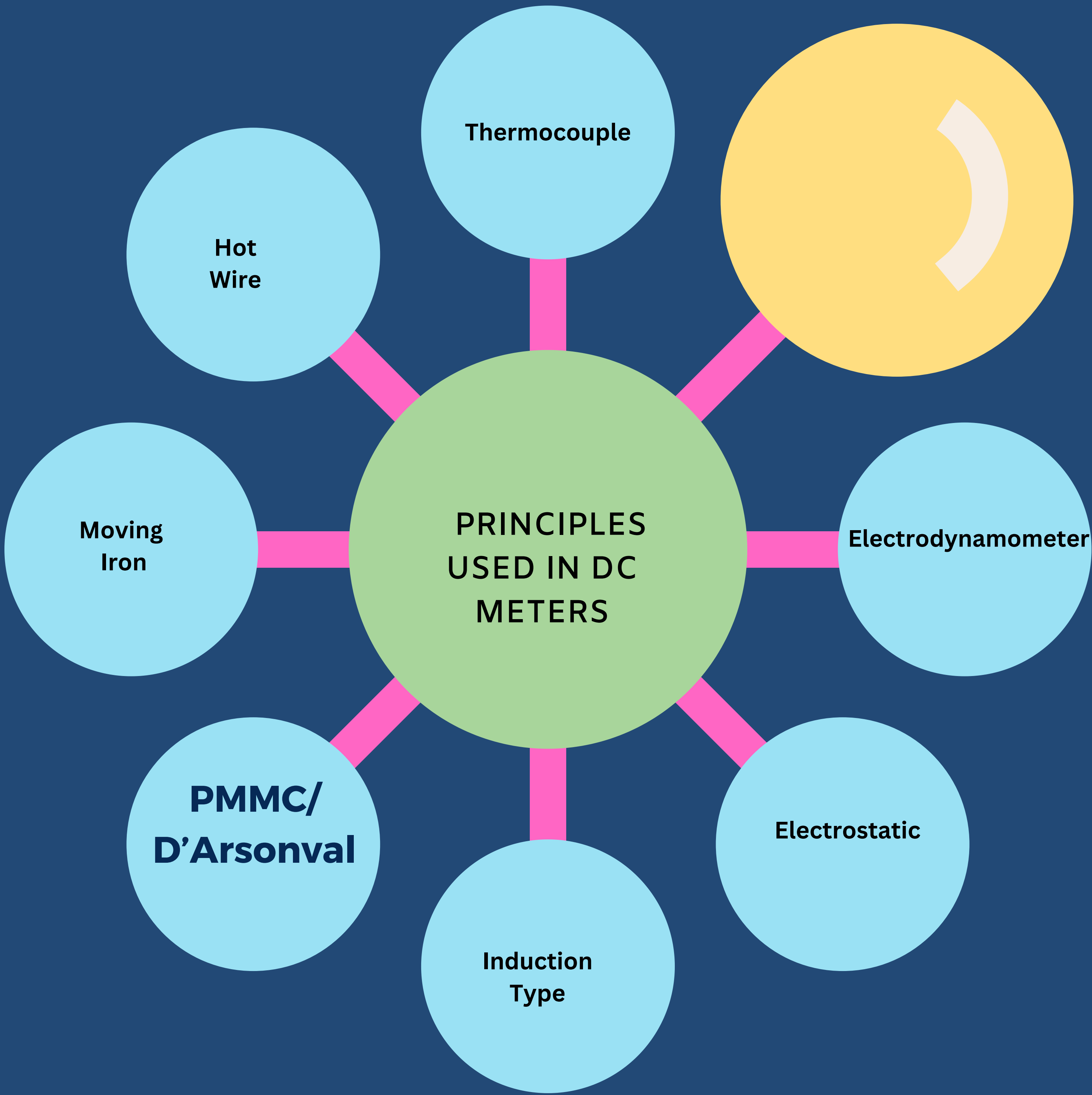
1. Voltage value across R1 as in Figure beside. The voltmeter shows reading of 5.45. Calculate the relative error, accuracy and percentage of accuracy



2. The measured value of a resistance is 20.25Ω and its true value is 20.22Ω. Determine the absolute error and percentage relative accuracy of measurement.

3. Discuss the difference between accuracy and precision of a measurement using appropriate diagram

02. DC AND AC METERS



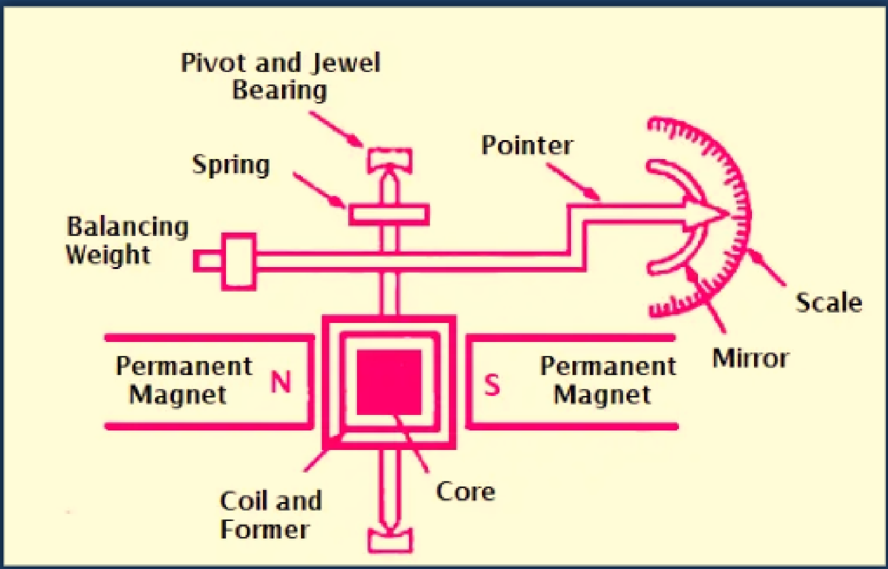
02. DC AND AC METERS

Introduction to Permanent Magnet Moving Coil (PMMC)

- A permanent magnet moving coil (PMMC) or D'Arsonval meter is one such instrument which is popularly used and has various applications.
- The PMMC instrument is the most accurate types and can be used for DC measurement only.
- The action of most commonly DC meter is based on the fundamental principle of the motor.
- The motor action is produced by the flow of a small current through a moving coil which is positioned in the field of a permanent magnet.
- Moving Coil Instruments are used for measuring DC quantities but can be used on AC systems when fed through bridge rectifiers.

02. DC AND AC METERS

Construction of PMMC



Principle Operation PMMC

- A coil suspended in the magnetic field of a permanent magnet in the shape of a horse-shoe.
- The coil is suspended so that it can rotate freely in the magnetic field. When current flows in the coil, the developed (electromagnetic) torque causes the coil to rotate.
- The electromagnetic torque is counterbalanced by a mechanical torque of control springs attached to the movable coil.
- The balance of torques, and therefore the angular position of the movable coil is indicated by a pointer against a fixed reference called a scale.

Deflecting Torque

$$Td = BANI \ (Nm)$$

B = flux density in Wb/m2 or Tesla (T)

N = number of coils

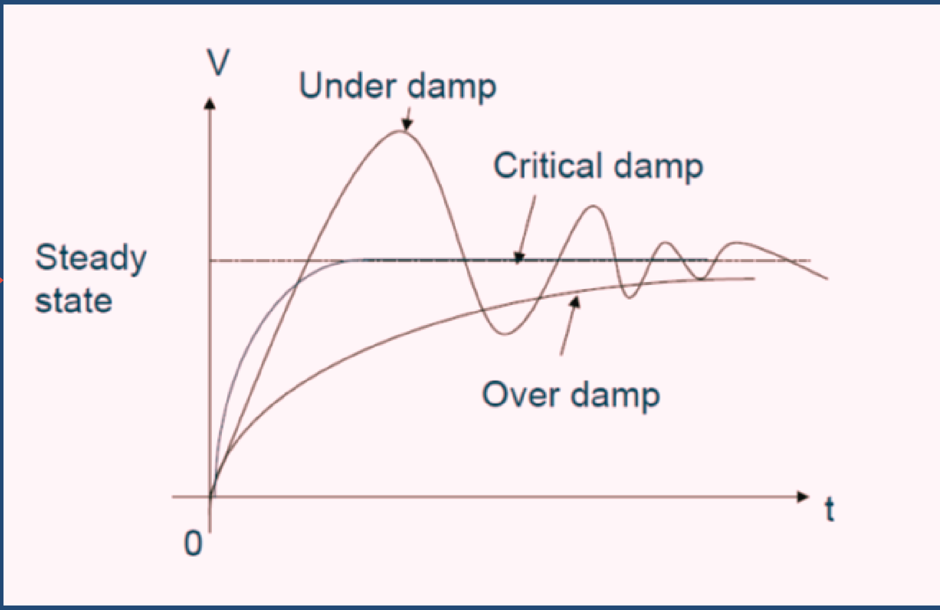
A = Area cross-section (length (l) x coil diameter (d)m2)

I = current flowing through the coil - Ampere

DAMPING CURVE IN AN ANALOGUE INDICATING INSTRUMENT

- The moving system of PMMC instrument will tent to move under the action of the deflecting torque.
- Works to speed up the pointer stops
- Pointer may oscillate before the show reading and damping torque required to accelerate the needle stops.

Damping Curve



- **Over damp** - pointer will move slowly and never reach the steady state. The value will be less than t**he actual value.**

- **Under damp** - pointer will oscillate until it finally reach the final value. The result is difficult to read.

- **Critical damp** - pointer to achieve the true value of free oscillations in a short time.

TUTORIAL 2

1

Flux density for a coil device in its air gap is 0.12T. The cross sectional area is $3.375 \times 10^{-2} m^2$. determine the required number of turns in the coil if the damping torque is 4.5Nm when the current flow is 100mA.

(Answer : 11111 turns)

2

A moving coil instrument has the following data
Number of turns = 100
Width of the coil = 20mm
Depth of the coil = 30mm
Flux density of the gap = 0.1 Wb/m^2
Calculate the deflecting torque when carrying a current of 10 mA.

(Answer : 6x10-5 Nm)

3

A moving coil instrument has the following data
Number of turns = 100
Width of the coil = 20mm
Depth of the coil = 30mm
Flux density of the gap = 0.1 Wb/m^2
The deflection torque(Td) = 30×10^{-6} Nm
Calculate the current through the moving coil.

(Answer : 5mA)

02. DC AND AC METERS

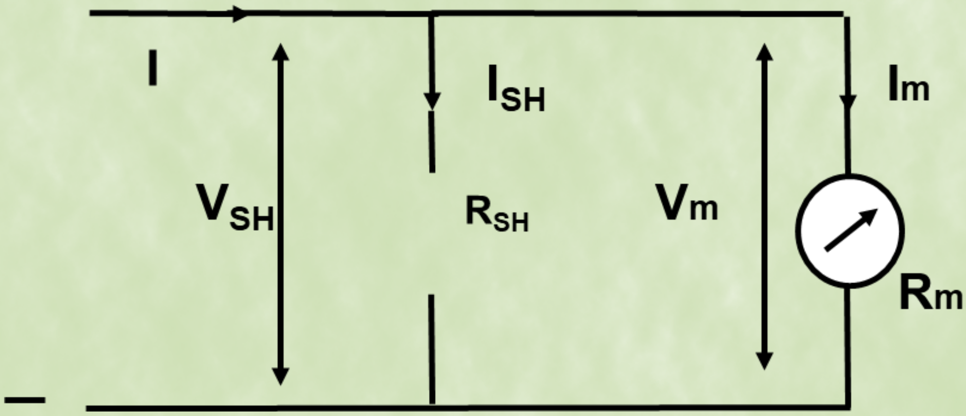
DC AMMETER

Single range DC Ammeter

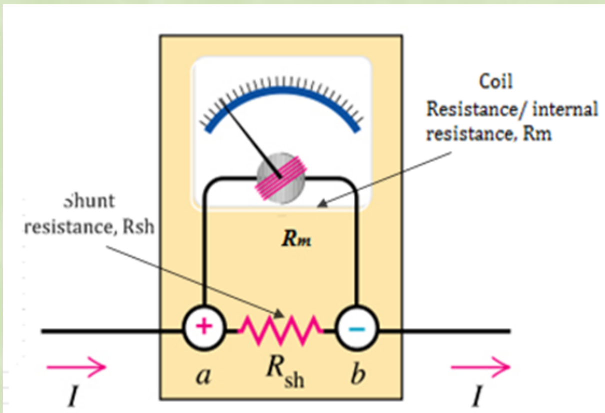
Multi range DC Ammeter

02. DC AND AC METERS

SINGLE RANGE DC AMMETER CIRCUIT



RSH	= Shunt resistance
Rm	= Internal resistance/coil resistance
ISH	= Shunt current
Im /Ifsd	= Meter current/ Full scale deflection current
I	= Current range



02. DC AND AC METERS

FUNCTION OF SHUNT RESISTANCE, RSH IN DC AMMETER

1

The basic DC ammeter circuit can be constructed using a PMMC by connecting a resistor in parallel with the meter movement.

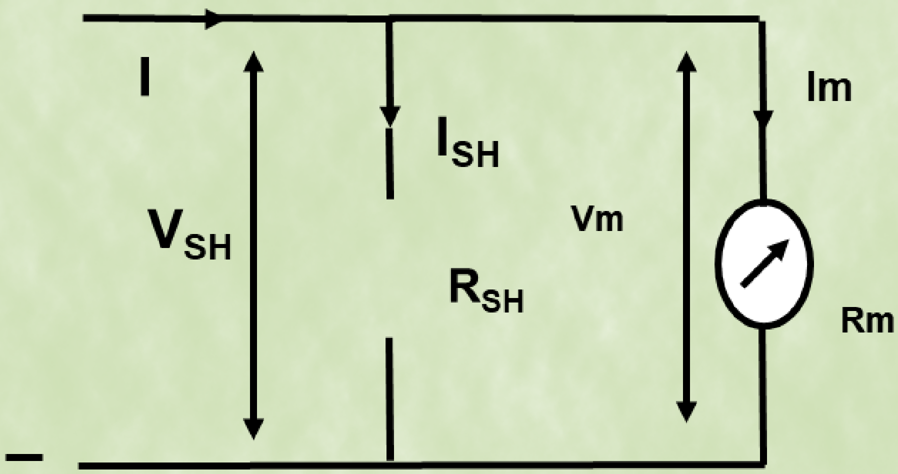
2

The parallel resistor is called a shunt resistor and its function to control the amount of current passing through the meter movement.

3

Thus the shunt resistance and PMMC can be thought of as forming a current dividing circuit.

DERIVATION EQUATION FOR SHUNT RESISTOR IN SINGLE RANGE DC AMMETER



Voltage equation

$$V_m = V_{SH}$$

$$I_m . R_m = I_{SH} . R_{SH}$$

$$R_{SH} = \frac{I_m R_m}{I_{SH}} \longrightarrow \text{equation 1}$$

Current equation

$$I = I_{SH} + I_m$$

$$I_{SH} = I - I_m \longrightarrow \text{to equation 1}$$

Example

A 2mA meter movement with an internal resistance of 100Ω is to be converted into a 0-150 mA. Calculate the value of shunt resistance required.

Solution:

$$R_m = 100\Omega, I_m = 2mA, I = 150mA$$

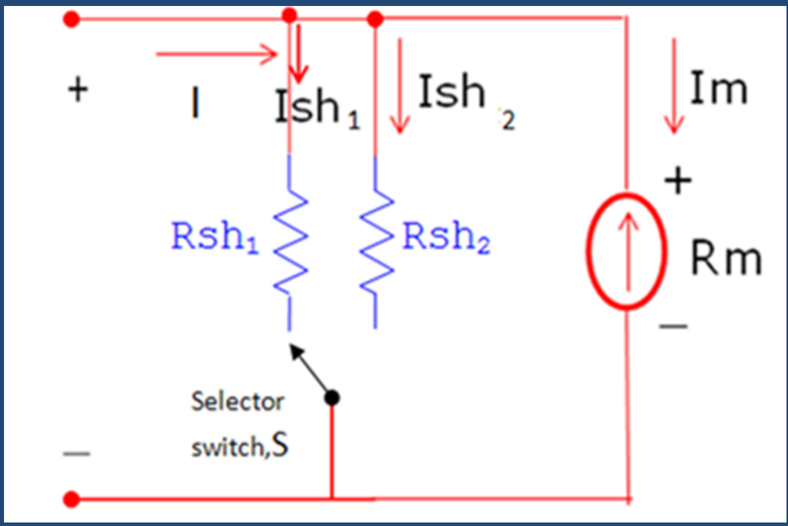
$$R_{SH} = \frac{\mathrm{I_m} . R_m}{I - \mathrm{I_m}}$$

$$R_{SH} = \frac{2m x 100}{150m - 2m}$$

$$R_{SH} = 1.351\Omega$$

02. DC AND AC METERS

TWO RANGE DC AMMETERS



The resistors are placed in parallel to give different current ranges.

Then, it becomes two shunts Rsh1 and Rsh2 and will give two different ranges of Ish1 and Ish2 .

The selector switch S is multiposition switch is used for the range changing .

Switch S also protects the meter movement from being damage during range changing.

02. DC AND AC METERS

TWO RANGE DC AMMETERS

When switch, S is connected at Rsh1, the shunt resistance Rsh1 and Rm are connected in parallel.

Using Ohm's law V=IR, since it is in parallel connection, Vm= voltage drop across the Rm IS EQUAL

Vsh1 = voltage drop across the Rsh1

$R_{sh1} = I_m R_m / I_1 - I_m$

When switch, Sis connected at Rsh2, the shunt resistance Rsh2 and Rm are connected in parallel.

Using Ohm's law V=IR, since it is in parallel connection,

Vm= voltage drop across the Rm

IS EQUAL

Vsh2= voltage drop across the Rsh2

$R_{sh2} = I_m R_m / I_2 - I_m$

02. DC AND AC METERS

Example

Design a two range dc miliammeter with a basic meter having a resistance 75Ω and full scale deflection for the current of 2mA. The required ranges are 0-10mA and 0-50mA.

Solution:

The first range is 0-10mA,

Give $I_1 = 10mA$, $I_m = 2mA$ and $R_m = 75\Omega$

$R_{sh1} = I_m R_m / I_1 - I_m$

$R_{sh1} = 2m(75)/(10m-2m)$

$= 18.75\Omega$

The second range is 0-50mA,

Give $I_2 = 50mA$, $I_m = 2mA$ and $R_m = 75\Omega$

$R_{sh2} = I_m R_m / I_2 - I_m$

$R_{sh2} = 2m(75)/(50m-2m)$

$= 3.125\Omega$

02. DC AND AC METERS

TWO RANGE DC AMMETERS (AYRTON)

When switch, S is connected at R_{sh1}, the shunt resistance R_{sh1} and R_m are connected in parallel.

Using Ohm's law $V=IR$, since it is in parallel connection, V_m= voltage drop across the R_m IS EQUAL

V_{sh1} = voltage drop across the R_{sh1}

$R_{sh1} = I_mR_m / I_1 - I_m$

When switch, Sis connected at R_{sh2}, the shunt resistance R_{sh2} and R_m are connected in parallel.

Using Ohm's law $V=IR$, since it is in parallel connection,

V_m= voltage drop across the R_m

IS EQUAL

V_{sh2}= voltage drop across the R_{sh2}

$R_{sh2} = I_mR_m / I_2 - I_m$

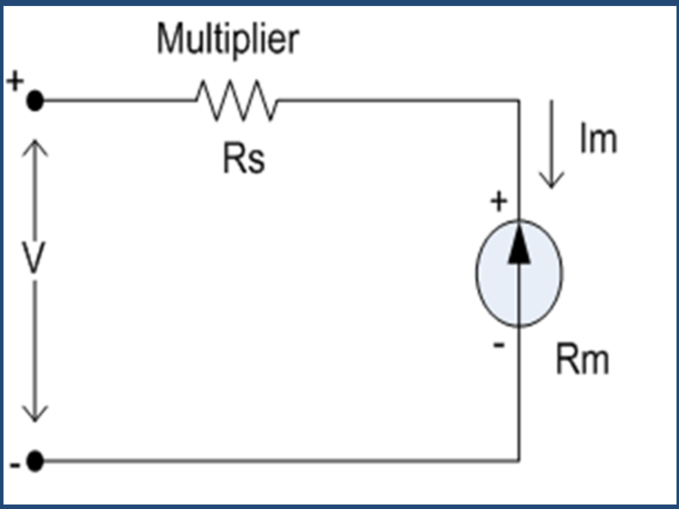
02. DC AND AC METERS

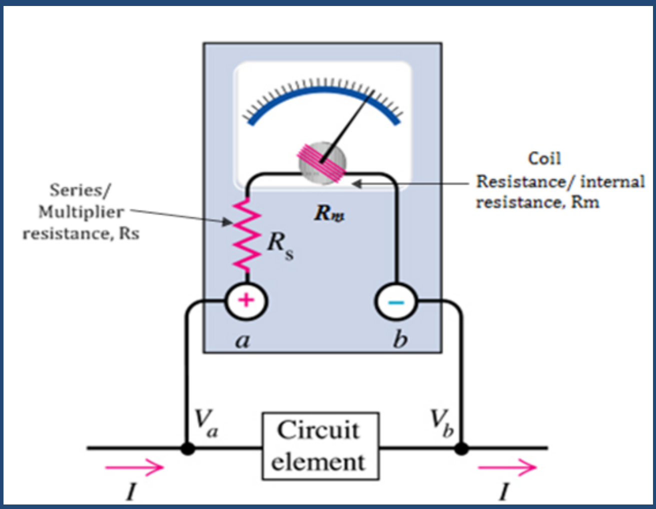
DC VOLTMETER

Single range DC Voltmeter

Multi range DC Voltmeter

SINGLE RANGE DC VOLTMETER CIRCUIT





Rs = Multiplier Resistor /Series resistor

Im = Meter current/full scale deflection current

Rm = Internal resistance/coil resistance

V = voltage range

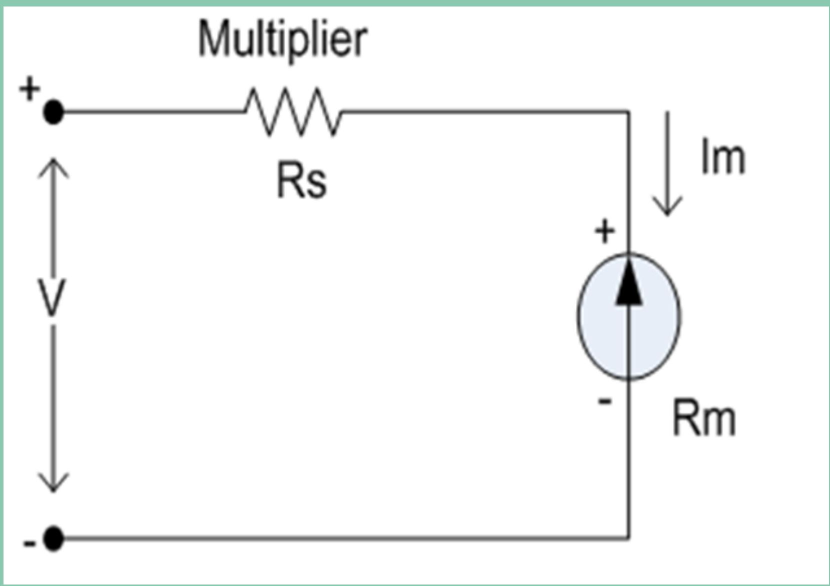
FUNCTION OF MULTIPLIER RESISTANCE, Rs IN DC VOLTMETER

A basic voltmeter can be constructed from a permanent magnet moving coil instrument by connecting a resistor in series with the meter.

The Series resistor is known as a multiplier resistance (Rs).

The purpose of multiplier resistance is to extend the voltage range of the meter and to limit the current flow through PMMC meter to a maximum full scale deflection current.

DERIVATION EQUATION FOR SERIES RESISTOR IN SINGLE RANGE DC VOLTMETER



From Voltage Kirchoff Law,

$$V = V_s + V_m$$

$$V = I_m R_s + I_m R_m$$

$$I_m R_s = V - I_m R_m$$

$$Rs = \frac{V}{\text{Im}} - Rm$$

Example

A moving coil instrument with a full scale deflection of 50μA and internal resistance of 500Ω is used as a voltmeter. Determine the value of the multiplier resistance needed to measure a voltage range of 0 – 10V.

Solution:

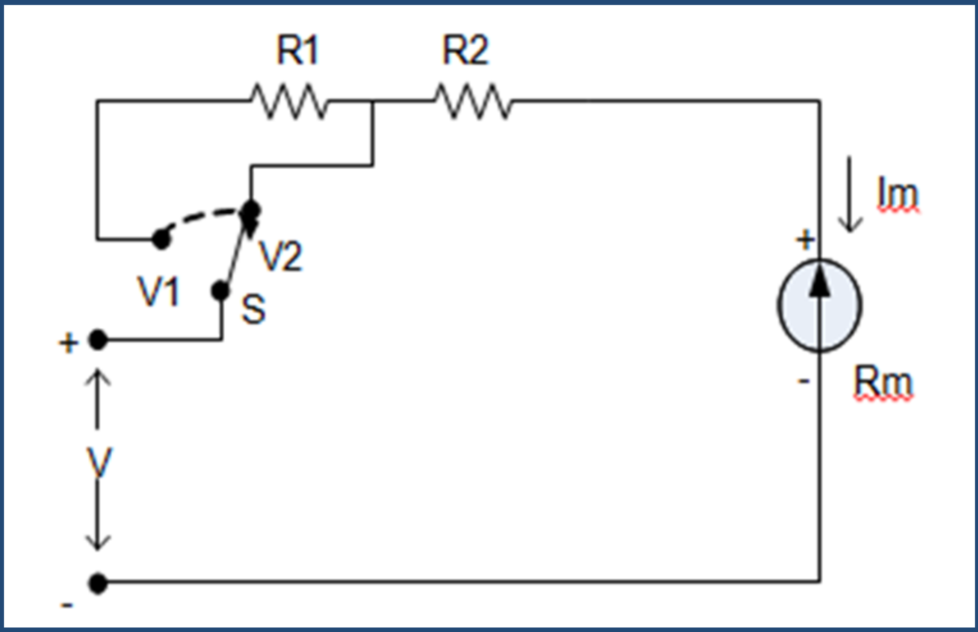
$$Rs = \frac{V}{\mathrm{Im}} - Rm$$

$$= \frac{10}{50\mu A} - 500$$

$$= 0.2x10^6 - 500$$

$$= 199.5k\Omega$$

TWO RANGE RANGE DC VOLTMETER CIRCUIT



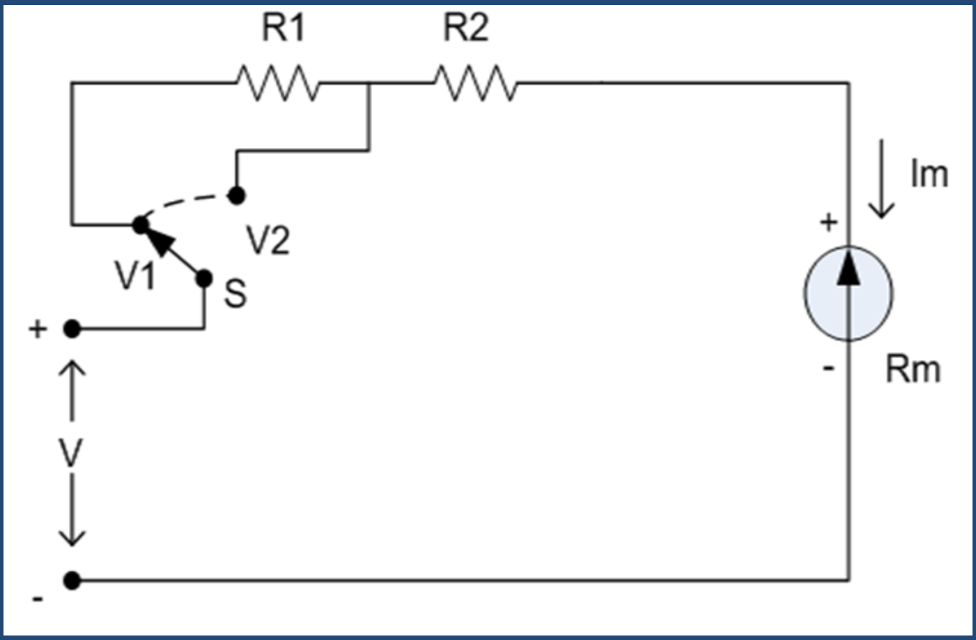
In position V2 (lowest voltage range), the multiplier resistance is only R2,

$$V2 = Im\ (R2 + Rm)$$

$$R2 + Rm = V2/Im$$

$$R2 = V2/Im - Rm \quad \ldots\ldots\ldots\ldots(1)$$

TWO RANGE RANGE DC VOLTMETER CIRCUIT



in position V1 (maximumvoltage range), the multiplier resistance are R1 and R2,

$$V1 = Im\ (R1 + R2 + Rm)$$

$$R1 + R2 + Rm = V1/Im$$

$$R1 = V1/Im - Rm - R2 \ldots\ldots\ldots\ldots(2)$$

TUTORIAL 3

1

Calculate the value of the shunt resistance required to convert a 1mA meter movement, with a 100Ω internal resistance into a 0 to 10 mA ammeter

(Answer: 11.11 Ω)

2

Design a two range DC ammeter with a basic meter having a resistance 50Ω and full scale deflection for the current of 2mA. The required ranges are 0-10mA and 0-25mA.Calculate the value of the required shunt resistances .

(Answer: 12.5Ω, 4.35Ω)

3

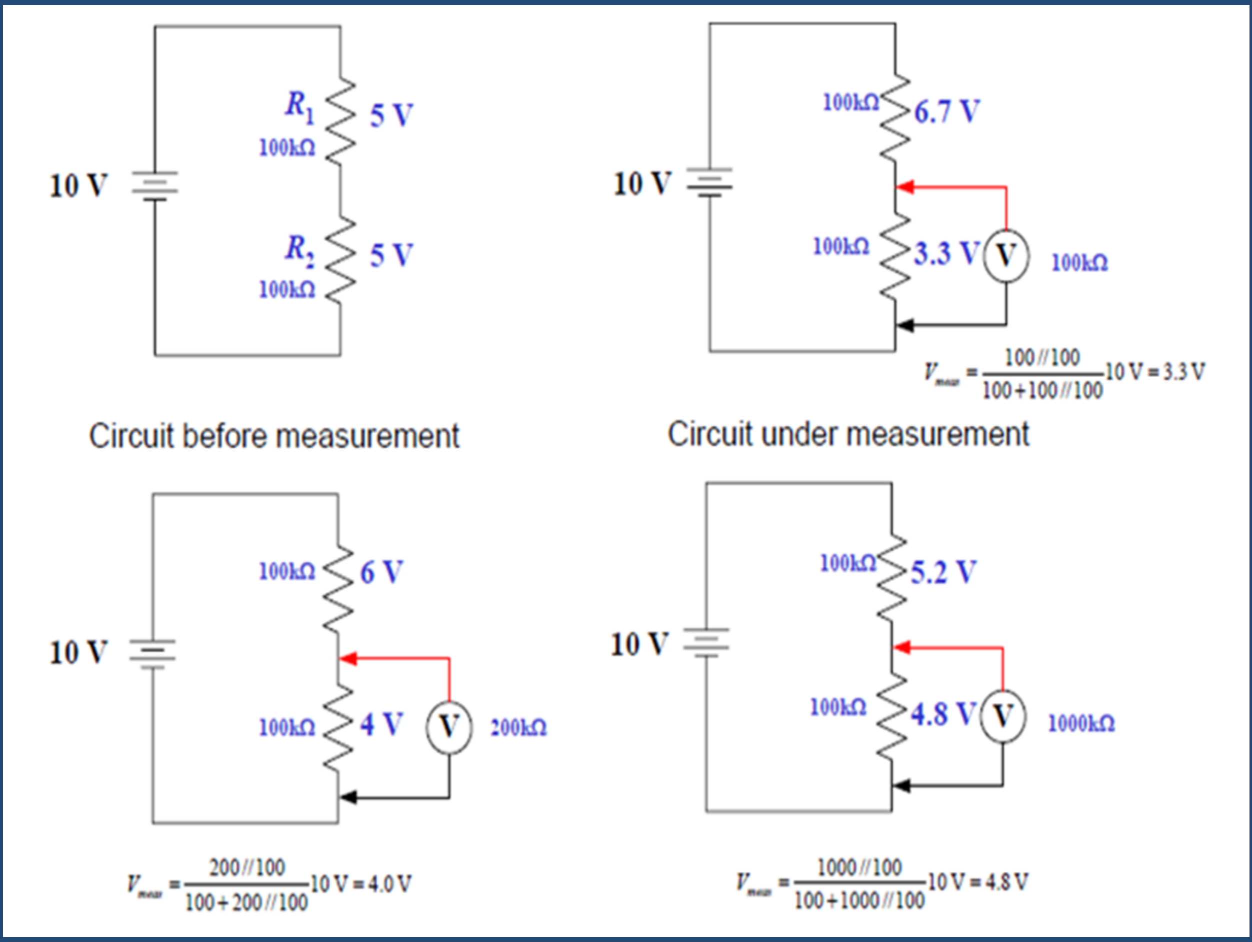
A moving coil instrument gives a full scale deflection with a current of 40μA, while the internal resistance of the meter is 500Ω. It is to be used as a voltmeter to measure a voltage range of 0-10V. Calculate the multiplier resistance needed.

(Answer: 249.5K Ω)

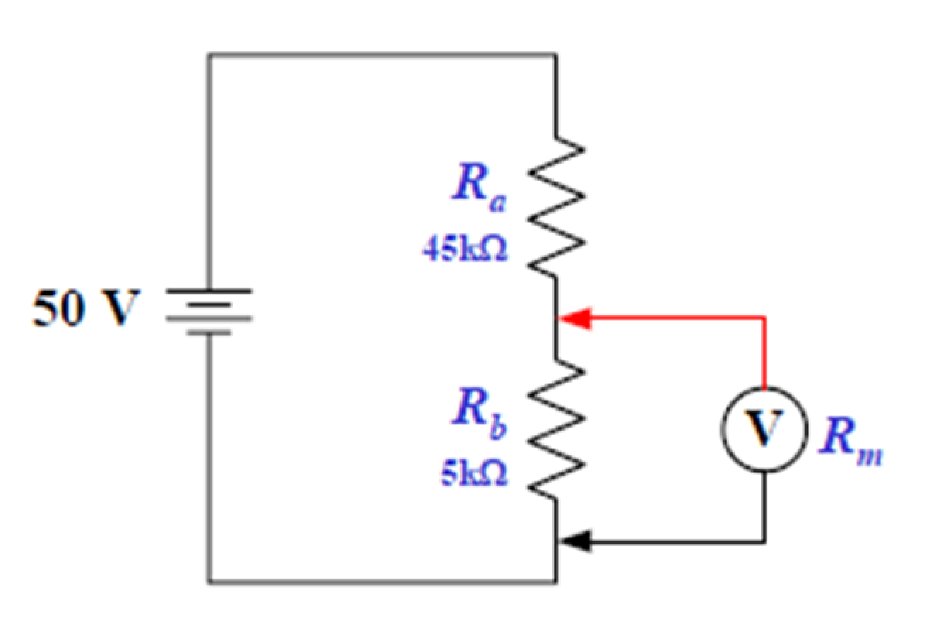
LOADING EFFECT

- Ideally, a perfect meter would have no loading effect, but all meters have some loading effect on the circuit they are measuring
- When voltmeter connected to circuit, it will lowers the effective resistance of the circuit and change the voltage reading
- Total resistance will decrease, so the voltage across component will also decrease. This is called voltmeter loading
- The resulting error is called a loading error/effect. The voltmeter loading can be reduced by using a high sensitivity voltmeter
- For high resistance circuits-use high sensitivity voltmeter to prevent loading effect
- Low resistance circuit, loading effect is less

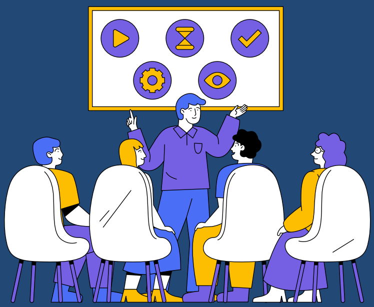
LOADING EFFECT



LOADING EFFECT



Range (V)	V_b (V)	Loading error (V)	Meter error (V)	Total error (V)	% error
5	4.78	-0.22	± 0.05	± 0.27	± 5.36
10	4.88	-0.12	± 0.1	± 0.22	± 4.40
30	4.95	-0.05	± 0.3	± 0.35	± 6.10



OHMMETER

Types of Ohmmeter

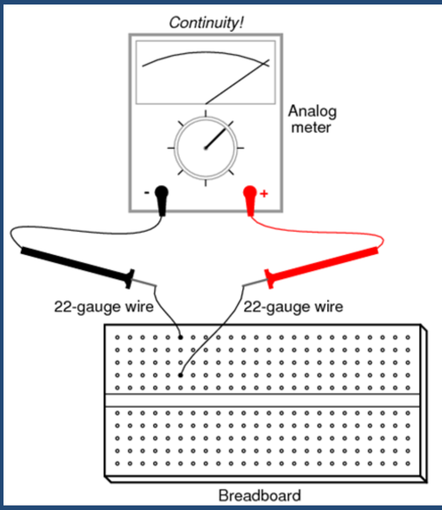
Series Ohmmeter

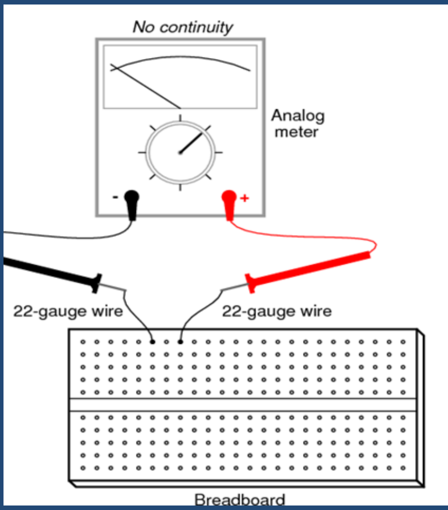
Shunt Ohmmeter

Functions of Ohmmeter

1. To measure resistance

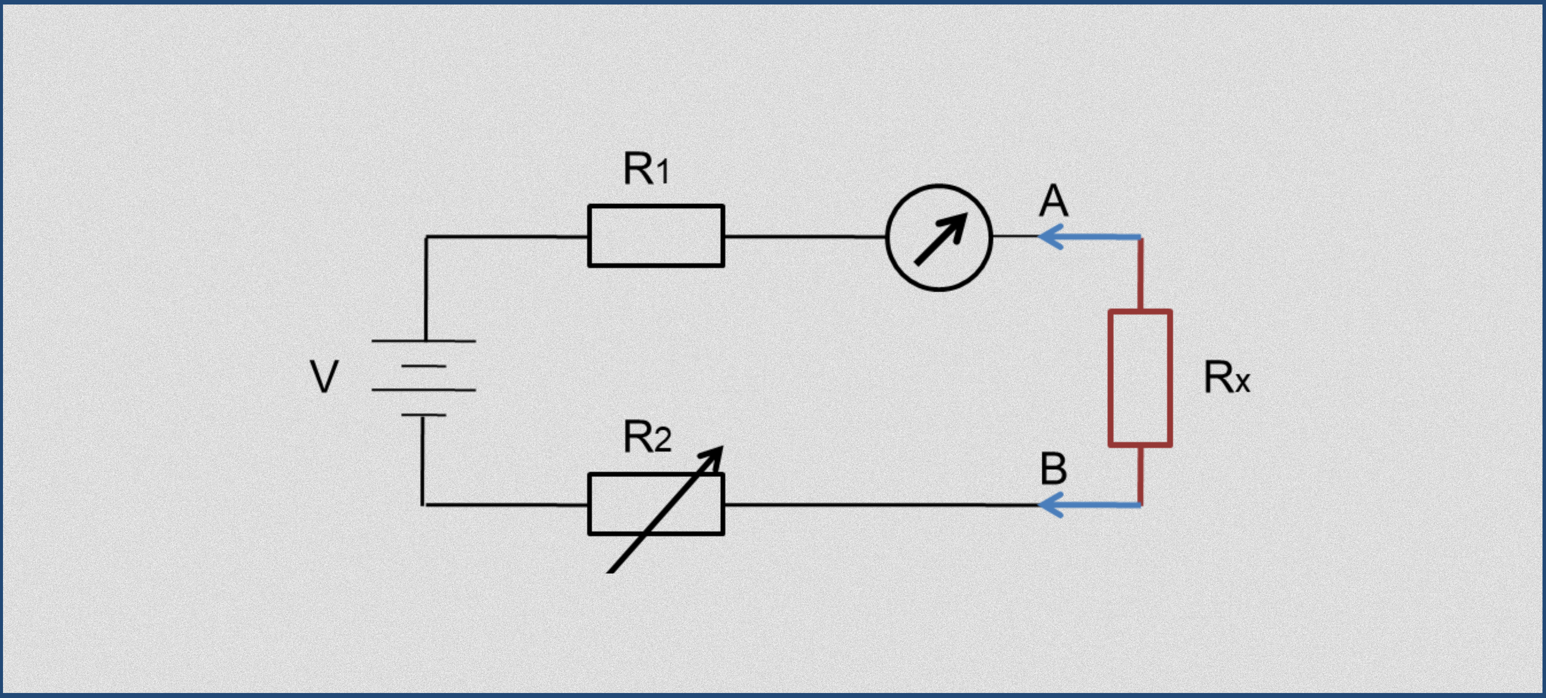
2. To check the continuity of electrical circuits and components





02. DC AND AC METERS

Series Type Ohmmeter

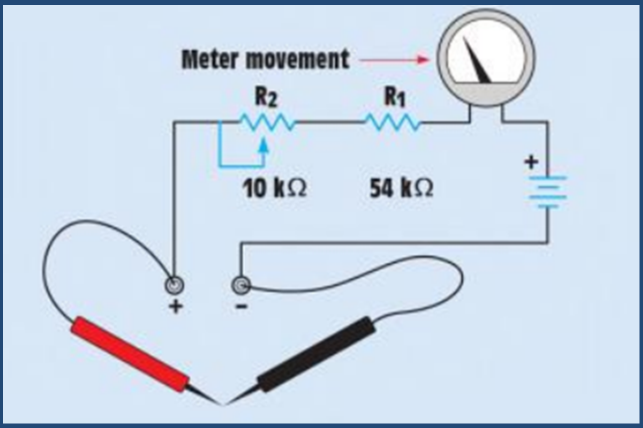


R1 = Limited Current Resistor

R2 = Zero Adjust Resistor

Rx = unknown Resistor

Rm = Meter Resistor



Fuctions of Series Ohmmeter Resistor

i. Current limiting resistance

A resistor inserted in an electrical circuit to limit the flow of current to some predetermined value. It is used chiefly to protect tubes and other components during warm up

ii. Zero adjusts resistance

A resistor inserted in an electrical circuit to adjusts the value of resistance to zero

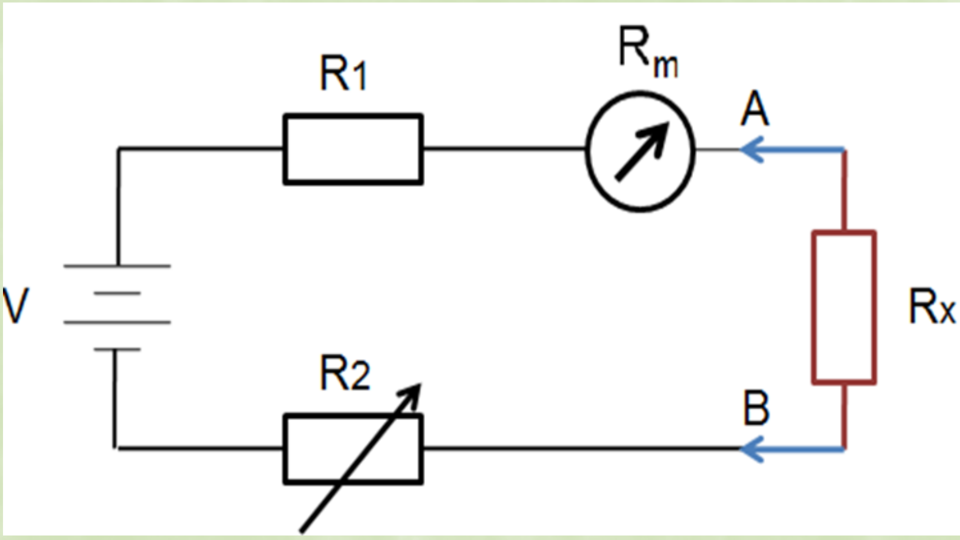
iii. Meter resistance

A resistance of the meter's armature coil

iv. Unknown resistance

A resistance that unknown value in a circuit

Derivation Equation for Series Ohmmeter



RT = Rm+R1+R2+Rx

Rx = RT - Rm - R1 - R2

Rx = VT/ IT - Rm - R1 - R2

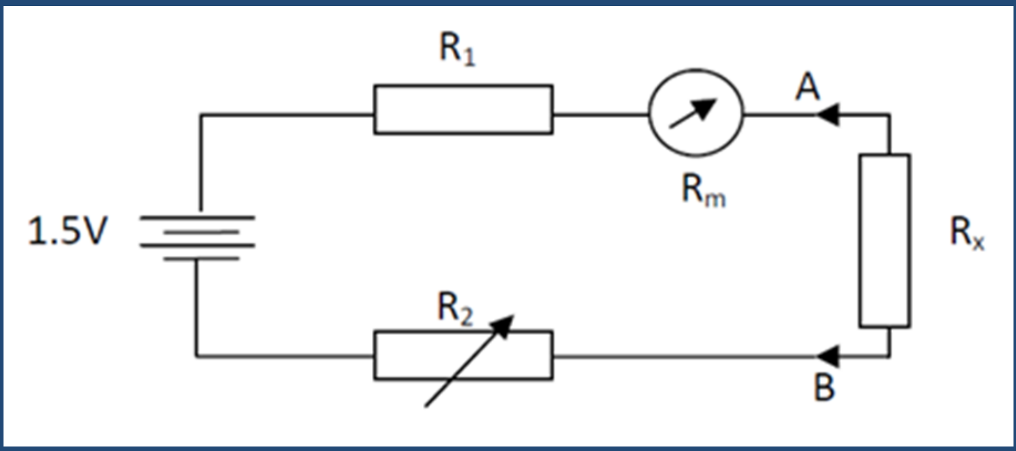
SERIES CONCEPT

$V_T = V_m\ V_{R1} + V_{R2} + V_x$

$I_T = I_m = I_x$

$R_T = R_m + R_1 + R_2 + R_x$

Example



Given battery of series ohmmeter is 1.5V and total resistance of R1 , R2 and Rm are 15kΩ,

a) Calculate IFSD if the unknown resistance, Rx = 0
b) Calculate RX if the ohmmeter scale at ¼ FSD, ½FSD, and ¾ FSD.

Solution :

When $R_x = 0\Omega$

$$R_T = (R_1 + R_m + R_2) + R_x$$

$$R_T = (15K) + 0$$

$$R_T = 15K\Omega$$

Find FSD of the meter, I_m

$$I_m = \frac{V}{R_T}$$

$$I_m = \frac{1.5}{15K}$$

$$I_m = FSD = 100\mu A$$

$$\boxed{When\ meter\ at\ \frac{1}{4}\ FSD}$$

$$I_m = \frac{1}{4}FSD = \frac{1}{4}(100\mu) = 25\mu A$$

$$R_X = \frac{V}{I_m} - (R_1 + R_m + R_2)$$

$$R_X = \frac{1.5}{25\mu} - (15K) = 45K\Omega$$

Solution :

$$\boxed{When\ meter\ at\ \frac{1}{2}\ FSD}$$

$$I_m = \frac{1}{2} FSD = \frac{1}{2}(100\mu) = 50\mu A$$

$$R_X = \frac{V}{I_m} - (R_1 + R_m + R_2)$$

$$R_X = \frac{1.5}{50\mu} - (15K) = 15K\Omega$$

$$\boxed{When\ meter\ at\ \frac{3}{4}\ FSD}$$

$$I_m = \frac{3}{4} FSD = \frac{3}{4}(100\mu) = 75\mu A$$

$$R_X = \frac{V}{I_m} - (R_1 + R_m + R_2)$$

$$R_X = \frac{1.5}{75\mu} - (15K) = 5K\Omega$$

Solution :

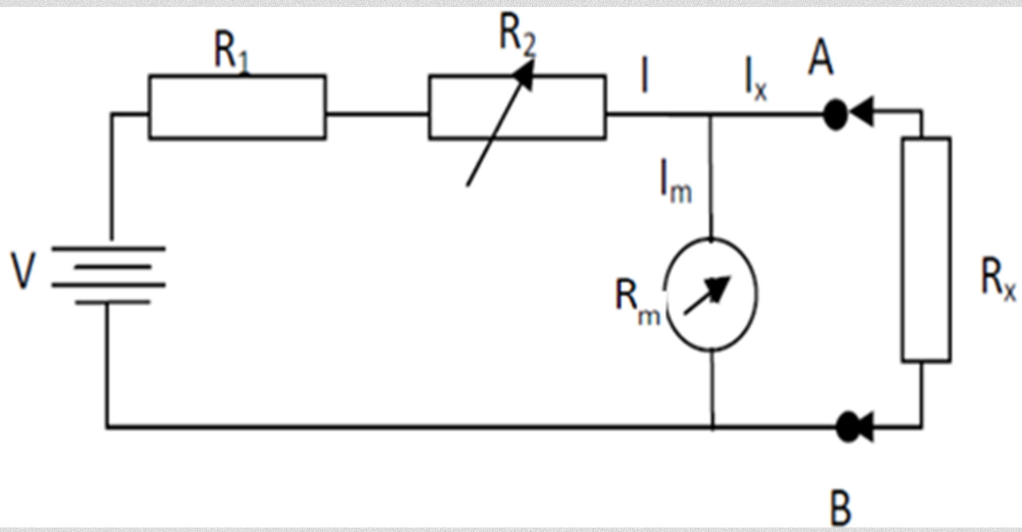
$\boxed{When\ meter\ at\ FSD}$

$$R_X = \frac{V}{I_m} - (R_1 + R_m + R_2)$$

$$R_X = \frac{1.5}{100\mu} - (15K) = 0\Omega$$

FSD	Im	Rx
100µA	¼ FSD= 25µA	45KΩ
	½ FSD=50µA	15KΩ
	¾ FSD =75µA	5KΩ
	FSD=100µA	0Ω

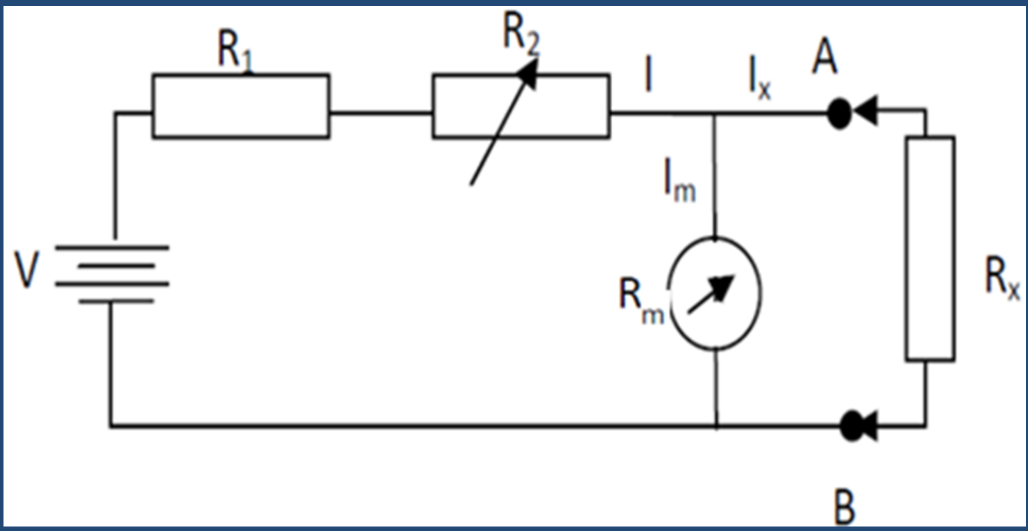
Shunt Type Ohmmeter



•Consist of a battery in series with an adjustable resistance R1 and a meter movement.

•The unknown resistance is connected in parallel with the meter

Derivation Equation for Shunt Ohmmeter



$$VKL \ldots\ldots V_m = I_m R_m$$

$$V_x = I_x R_x$$

$$V_m = V_x$$

$$I_m R_m = I_x R_x$$

Derivation Equation for Shunt Ohmmeter

$$CKL \ldots\ldots I_x = I - I_m$$

$$R_x = \frac{I_m\ R_m}{I_x}$$

$$\boxed{R_x = \frac{I_m\ R_m}{I - I_m}}$$

PARALLEL CONCEPT

$V_m = V_x$

$I = I_m + I_x$

TUTORIAL 4

1

Given PMMC with resistance 100Ω was using in series ohmmeter. R1 = 300Ω, R2 = 200Ω and supply voltage = 9V. When connected with Rx, the reading shows 1mA. Find the value of Rx

(Answer: 8.4KΩ)

2

Given battery of series ohmmeter is 2V and total resistance of R1,R2 and Rm are 2kΩ,

a) Calculate IFSD if the unknown resistance, Rx = 0

(Answer: 1mA)

b) Calculate RX if the ohmmeter scale at ¼FSD, ½ FSD, and ¾ FSD

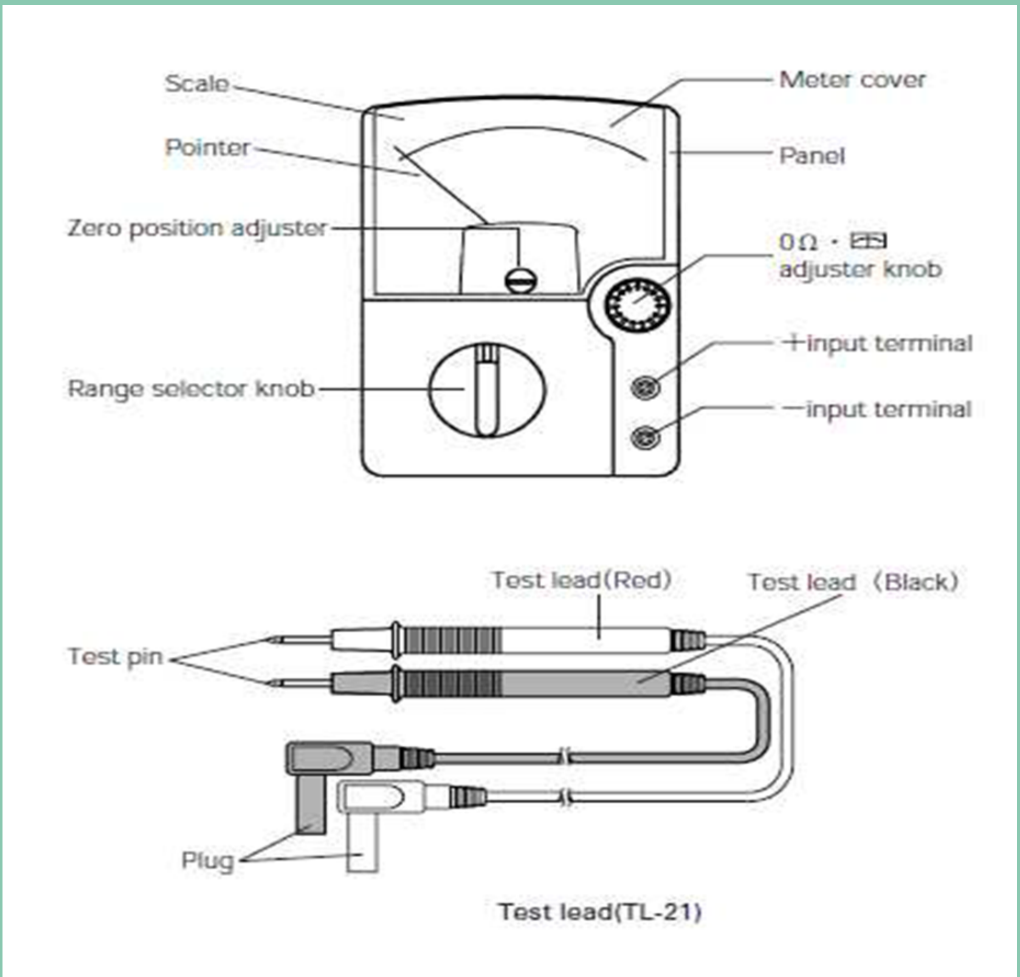
(Answer: Rx=6KΩ, Rx=4KΩ, Rx=666.7KΩ)

3

The shunt ohmmeter circuit below uses a 4μA total current with an internal resistance of 400Ω. The value of the current limiting resistor, R1 4KΩ, Calculate RX when the current is 0A, ¼FSD, ½ FSD and IFSD

(Answer: Rx=0Ω, Rx=133.3Ω, Rx=400Ω, Rx=∞Ω

ANALOGUE MULTIMETER



The multi meter is a common multi purpose instrument used to measure electricalquantities in a circuit (example: resistance, voltage & current)

Analogue Multimeter consist of:

i. DC Ammeter

SCALES OF ANALOGUE MULTIMETER

Ohmmeter scale

AC voltage scale only for 10V (Red scale)

DC voltage - Current and AC Voltage scale (Scale : 10, 50, 250)

SIGNIFICANCE OF METER SENSITIVITY

Sensitivity is the ratio of total resistance of the voltmeter to its full scale reading in volt, expressed
in Ohms per Volt.

Sensitivity (S) = 1/Ifsd (Ω/V)

Multimeters must have a high sensitivity of at least 20kΩ/V otherwise their resistance on DC voltage ranges may be too low to avoid upsetting the circuit under test and giving an incorrect reading.

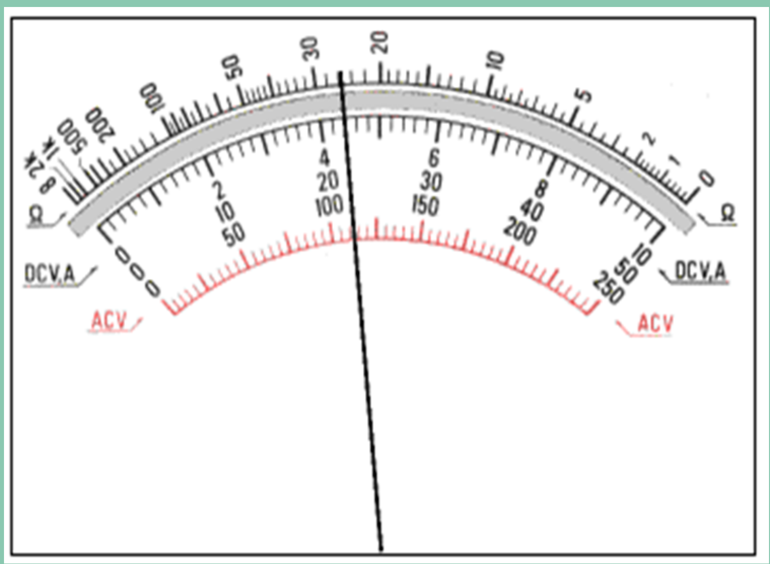
ANALOGUE MULTIMETER SAFETY PRECAUTIONS

- Never apply power to the circuit while measuring resistance with a multimeter.
- Connect the multimeter in series with the circuit for current measurements, and in parallel for voltage measurements.
- Be certain the multimeter is switch to AC before attempting to measure AC circuits.
- Observe the proper DC polarity when measuring DC values.
- When finished with a multimeter use, switch it to OFF position, if available. If there is no OFF position, switch the multimeter to the highest voltage position.
- Always start with the highest voltage or current range.
- Adjust the “0 ohm” reading after changing resistance ranges and before making a resistance measurement.
- Be certain to read AC measurements on the AC scale of a multimeter.

HOW TO USE AN ANALOGUE MULTIMETER?

Steps to measure voltage

i. Set the voltage type to test AC or DC voltage
ii. Start with the highest range
ii. Place the +ve and –ve probe to the ground terminal and positive terminal
iii. Connect the voltmeter in parallel with the load
iv. Read the move of the pointer by DCV.A scale.



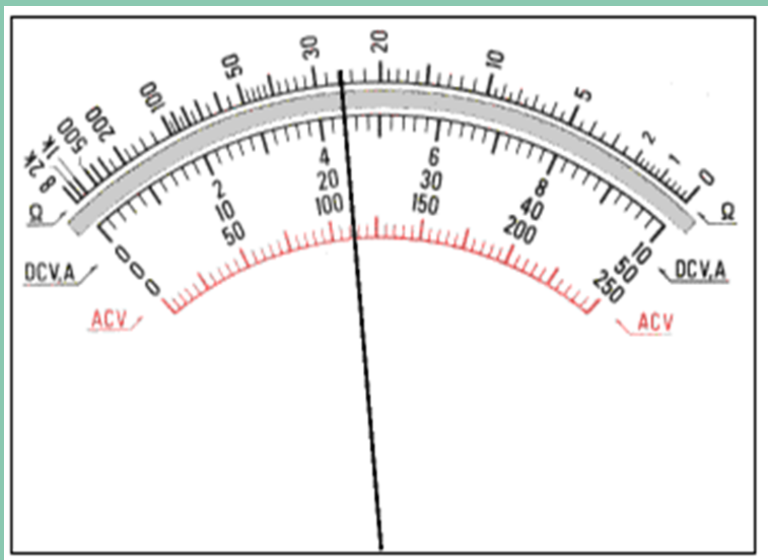
Sample readings on the scales shown:

DC 10V range: 4.4V (read 0-10 scale directly)
DC 50V range: 22V (read 0-50 scale directly)
AC 10V range: 4.45V (use the red scale, reading 0-10)
AC 10V range: 4.45V (use the red scale, reading 0-10)

HOW TO USE AN ANALOGUE MULTIMETER?

Steps to measure current

i. Set the correct current range DCmA
ii. Start with the highest range
iii. Connect the Ammeter in ***series*** with the load by following the right polarity (positive lead to positive source and negative lead to negative source).
iv. Read the move of the pointer by DCV.A scale.



Sample readings on the scales shown:

DC 2.5mA range: 1.1mA (read 0-250 and divide by 100)
DC 25mA range: 11mA (read 0-250 and divide by 10)

HOW TO USE AN ANALOGUE MULTIMETER?

Steps to measure resistor value

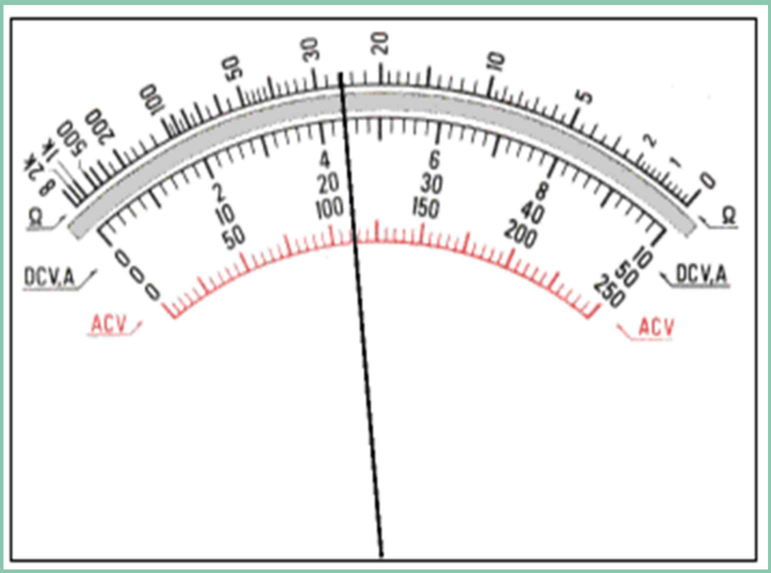
i. Do calibration before use multimeter to measure resistor. Put meter probes together at range 1K and adjust the "0 ADJ" until the pointer reads zero .

ii. Start with the highest ohm range.

iii. Choose a range that the resistance will be near the middle of the scale.

iv. Put the probes across the component. The circuit to be tested must be in power off status during the resistance measurement.

v. Read the move of the pointer by Ω scale.



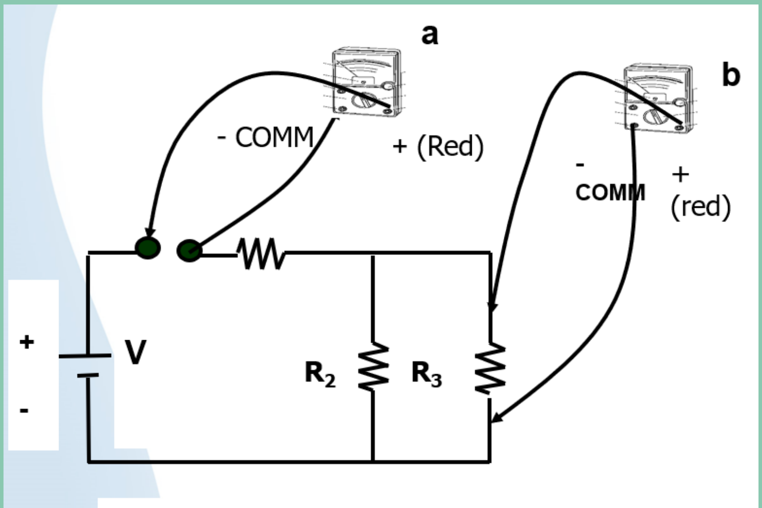
Sample readings on the scales shown:

26 × 1K range: 26KΩ

26 × 10K range: 260KΩ

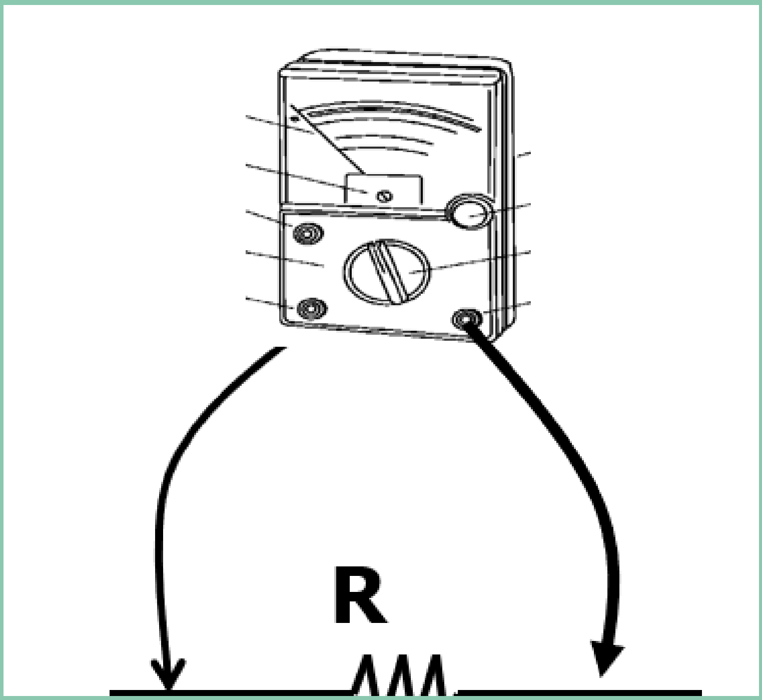
HOW TO MEASURE MVOLTAGE, CURRENT AND RESISTANCE USING ANALOGUE MULTIMETER?

CURRENT AND VOLTAGE



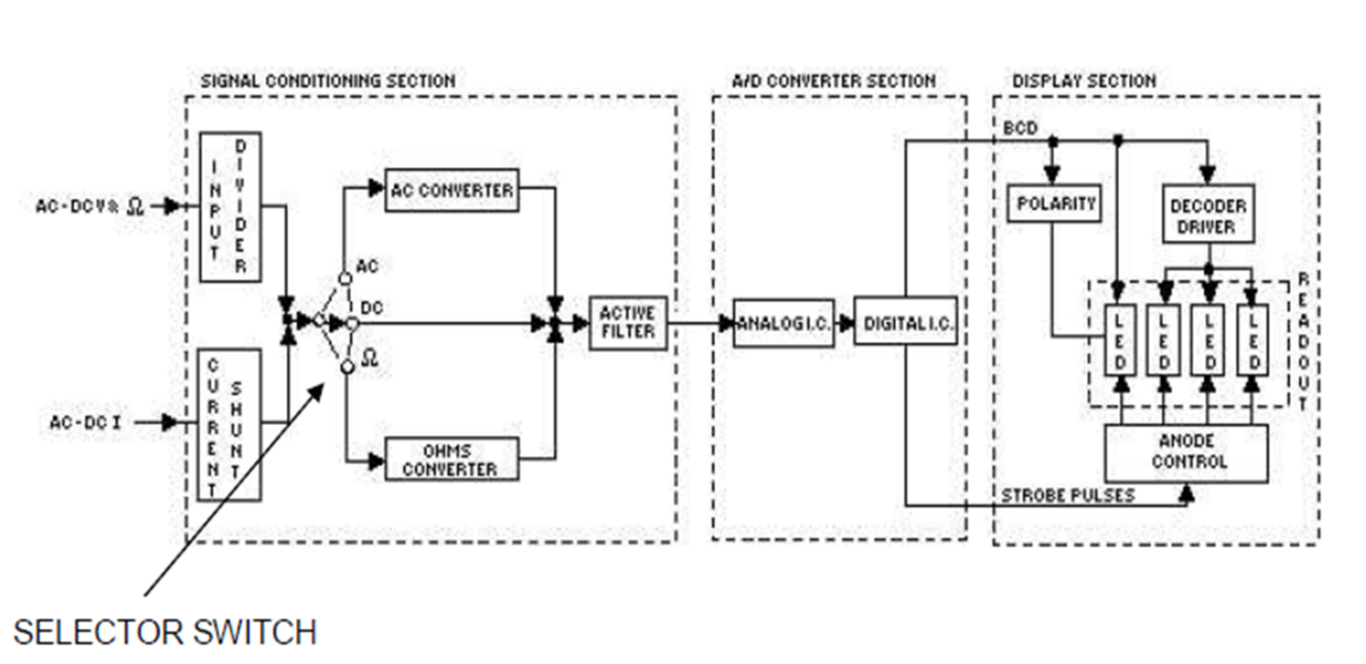
Current measurement (a) – in series
Voltage measurement (b)- in parallel

RESISTANCE



DIGITAL MULTIMETER

BLOCK DIAGRAM



FUNCTION OF EACH BLOCK

Signal Conditioning

The Signal Conditioning section provides a DC analog voltage - to applied to the ADC section. This task is accomplished by the input voltage divider, current shunts, AC converter, ohm converter, active filter and associated switching.

Analog-to- Digital Converter (A/D Converter)

Changes the dc output voltage from Signal Conditioning section to digital information.

Display

Display the value from the A/D converter section. Eg.LED/seven segment (Light Emitting Diode) readout.

ADVANTAGES AND DISADVANTAGES OF DIGITAL MULTIMETER

Advantages

Higher accuracy and resolution
Easier to read, display as a number
No parallax errors
Reduce human error
Digital meters can be safely connected in reverse

Disadvantages

May require memory
More expensive and also requires a power supply
Repeated inputs are possible

DIFFERENTIATE BETWEEN ANALOGUE MULTIMETER AND DIGITAL MULTIMETER

No	Aspects	Analog multimeter	Digital multimeter
1	Power supply	Not required	Required
2	Visual indication of changes in the reading	Better	Not that much better
3	Effect of electric noise	Less	More
4	Accuracy	Less	High
5	Interface of the with external equipment	Not possible	Possible
6	Construction	Simple	Complicated
7	Cost	Less	More

DIGITAL MULTIMETER SAFETY PRECAUTIONS

1.Never apply power to the circuit while measuring resistance with a multimeter.

2.Connect the multimeter in series with the circuit for current measurements, and in parallel for voltage measurements.

3.Be certain the multimeter is switched to AC before attempting to measure AC circuits.

4.Observe proper DC polarity when measuring DC circuits.

5.Always start with the highest voltage or current range.

6.Observe the general safety precautions for electrical and electronic devices.

02. DC AND AC METERS

CLAMP METER

- A clamp meter is a type of meter which measures electrical current (AC) in the conductor without the need to disconnect the wiring which is the current flowing through it.
- Clamp meter is having two jaws which open to allow clamping around an electrical conductor.
- These meters are also known as tong testers or Amprobes.
- The advantage of this meter over an ammeter is that we do not have to break the circuit to measure the current.

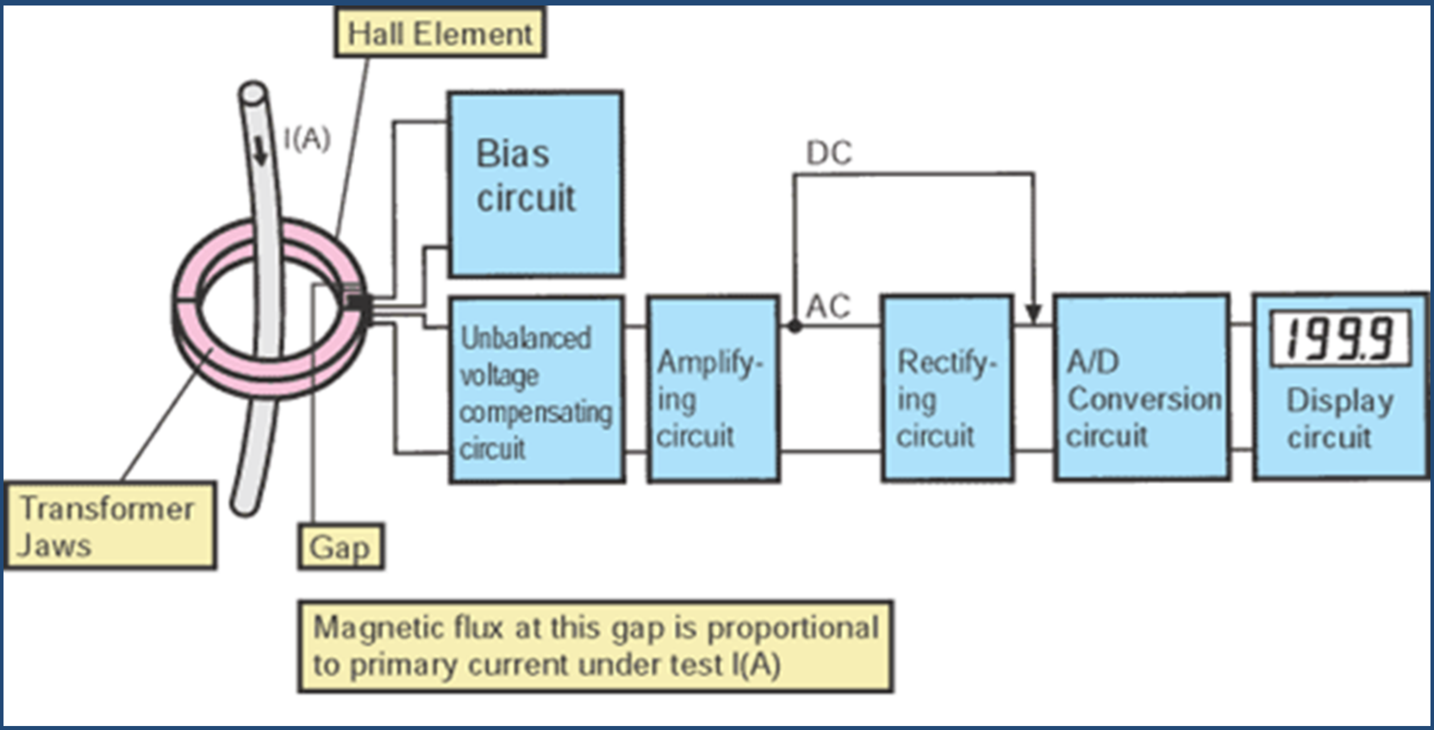
CLAMP METER

- So we usually use it to measure current in a circuit where it is dangerous of difficult to break the circuit to place ammeter in line for the test.

- We clamp the meter onto the conducting wire at the point where we want to measure the current.

- We usually use this meter to measure alternating current (AC) values higher than 10A. Direct currents and very low AC currents (milliamps) are more difficult to measure.

THE BASIC PRINCIPLE OF CLAMP METER



Clamp meter are consists of Transformer Jaws, Hall element and GAP.

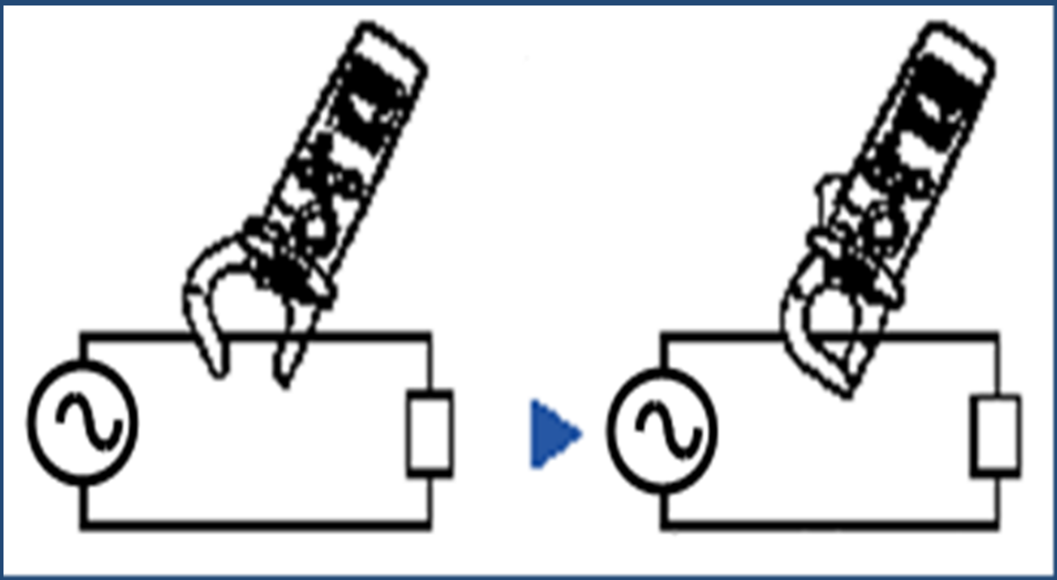
Hall elements are used as a sensor to detect DC current and placed across a gap created by cutting off part of the transformer jaws.

When there occurs a flow of magnetic flux proportional to both AC and DC primary currents in the transformer jaws this hall element detects the magnetic flux and takes it out as an output voltage.

OPERATION OF CLAMP METER

- **AC clamp meters operate on the principle of current transformer (CT) used to pick up magnetic flux generated as a result of current flowing through a conductor.**
- **Assuming a current flowing through a conductor to be the primary current.**
- **This current proportional to the primary current by electromagnetic induction from the secondary side (winding) of the transformer .which is connected to a measuring circuit of the instrument.**
- **This result an AC current reading on the digital display (in the case of digital clamp meters) as illustrated by the block diagram.**

THE CLAMP METER CONNECTION FOR ALTERNATING CURRENT MEASUREMENT



Clamp meter circuit for AC current measurement

- Set the Function switch to the 40 or 200A AC range.
- Press the jaw trigger and clamp around, fully enclosing a single conductor. Do not allow a gap between the two halves of the jaw (Take a measurement at the centre of the core of the clamped portion to minimize measuring errors).
- If two wire parallel lines are clamped, current measurement cannot be made.
- Read the ACA value on the LCD.

03. OSCILLOSCOPE AND SIGNAL GENERATOR

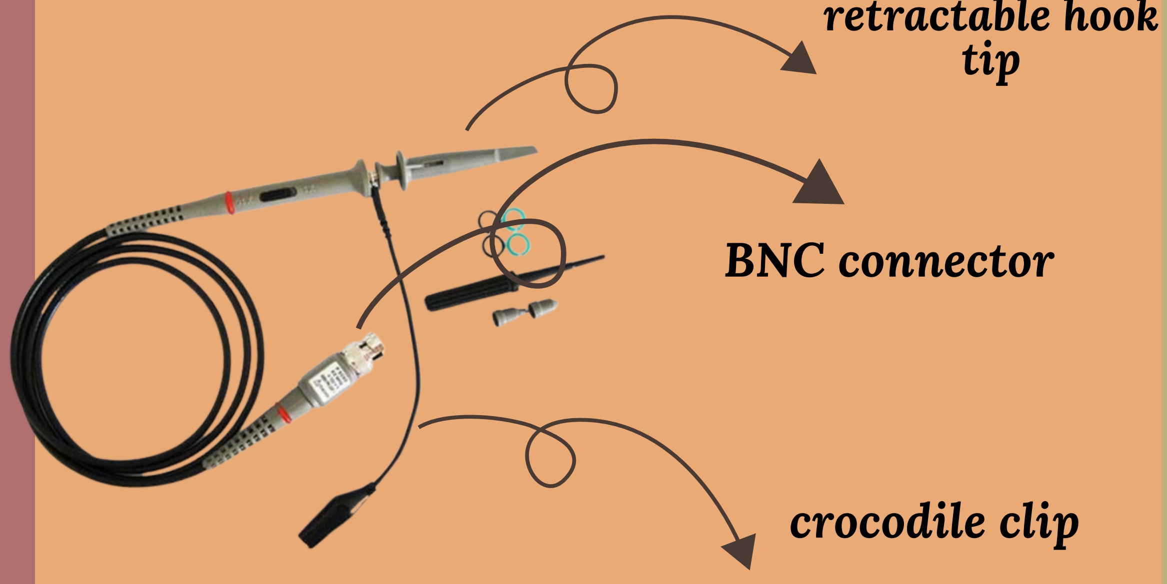
FUNCTION OF ANALOGUE AND DIGITAL OSCILLOSCOPE

Oscilloscope is a device that allows the amplitude of electrical signals, whether they be voltage, current , power, etc., to be displayed primarily as a function of time (the basic instrument for the study all types of waveforms).

MAIN BASIC FUNCTION OF OSCILLOSCPE

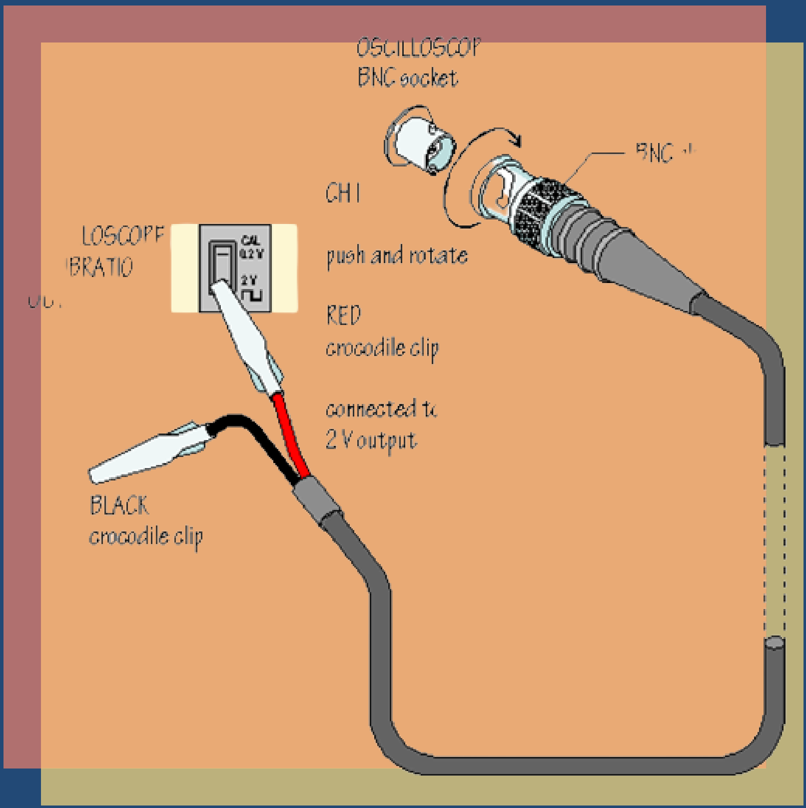
i. Measure AC/DC voltage
ii. Measure AC/DC current
iii. Measure the time and frequency
iii. Measure the phase differential between two waveforms

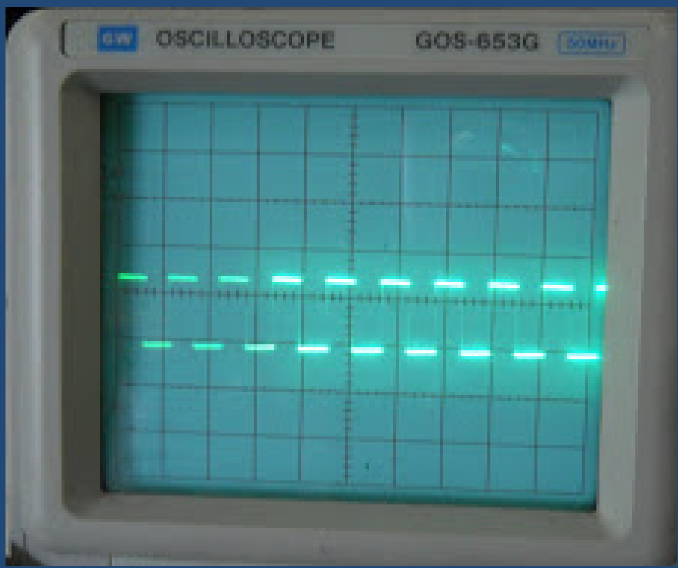
OSCILLOSCOPE PROBE



CALIBRATION OSCILLOSCOPE

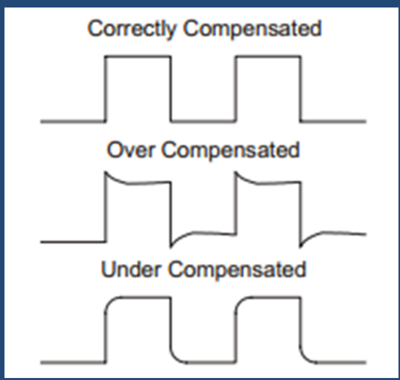
- Oscilloscope probe shows the potential difference between the two terminals of the probe.
- The terminal ending with a hook probe is usually connected to the node in the circuit whose voltage is of interest.
- The other terminal is usually connected to the ground.
- The probes are attached to input channels of the oscilloscope.
- Most oscilloscopes have at least two input channels and each channel can display a waveform on the screen.
- Multiple channels are useful for comparing waveforms





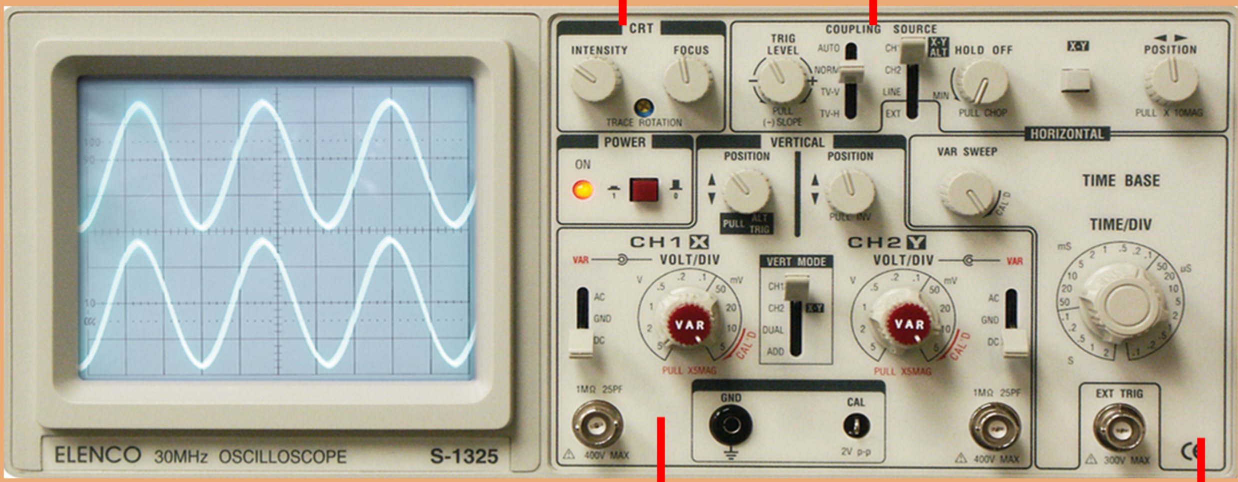
Calibration must be square wave Volt/div
Depend on value of "CAL" on osc
Time/div Must be 0.5ms to get Freq. = 1KHz

A poorly adjusted probe can make your measurements less accurate.
The figure shows what happens to measured waveforms when using a probe not properly compensated

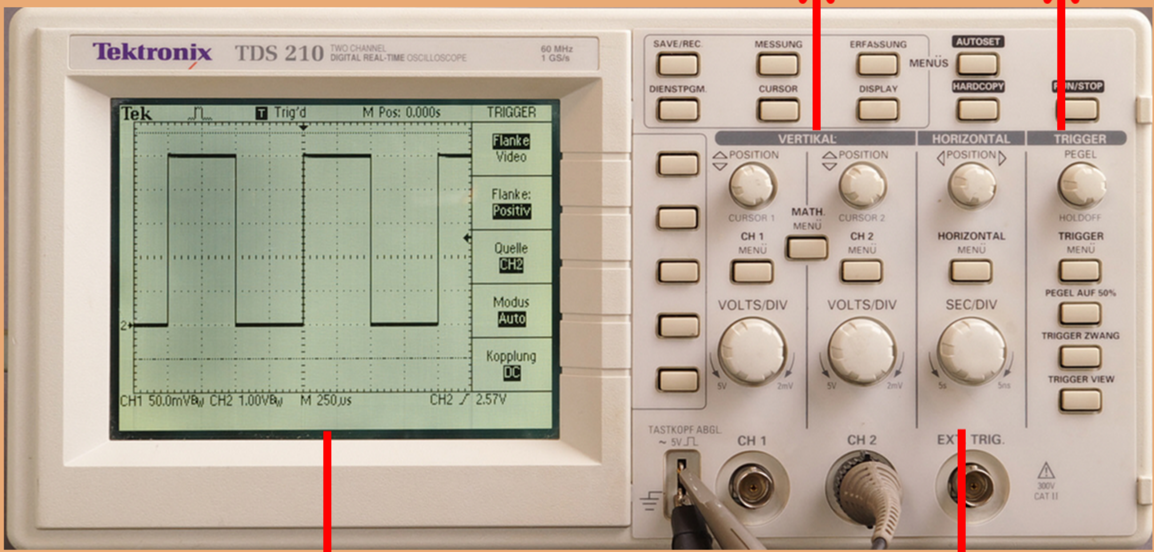


ANALOGUE & DIGITAL OSCILLOSCOPE

ANALOG OSCILLOSCOPE



DIGITAL OSCILLOSCOPE



4 MAIN SECTION ON FRONT PANEL

- **Display Control**
- **Vertical Control,**
- **Horizontal Control**
- **Trigger Control**

VERTICAL CONTROL

- Vertical controls can be used to position and scale the waveform vertically.
- Also can be used to set the input coupling and other signal conditioning.

DISPLAY CONTROL

- An oscilloscope’s front panel include a display screen and the knobs, buttons, switches,
  and indicators used to control signal display.
- As mentioned at the front of this section, front-panel controls are usually divided into vertical, horizontal and trigger section.
- Its also includes input connector.

FUNCTION OF DISPLAY CONTROL

1) POWER SWITCH ON/OFF

To indicate the power on & off. When the equipment is turn on, green light will appear

2) POWER LAMP

This LED lamp lights when power is turned on

3) INTENSITY KNOB

It can control the brightness of the spot or trace.

4) FOCUS KNOB

To make the signal (trace) displayed more sharp (to clearest line trace

5) SCALEILLUM KNOB

This is used to adjust scale brightness. If this knob is turned clockwise, brightness is increased.

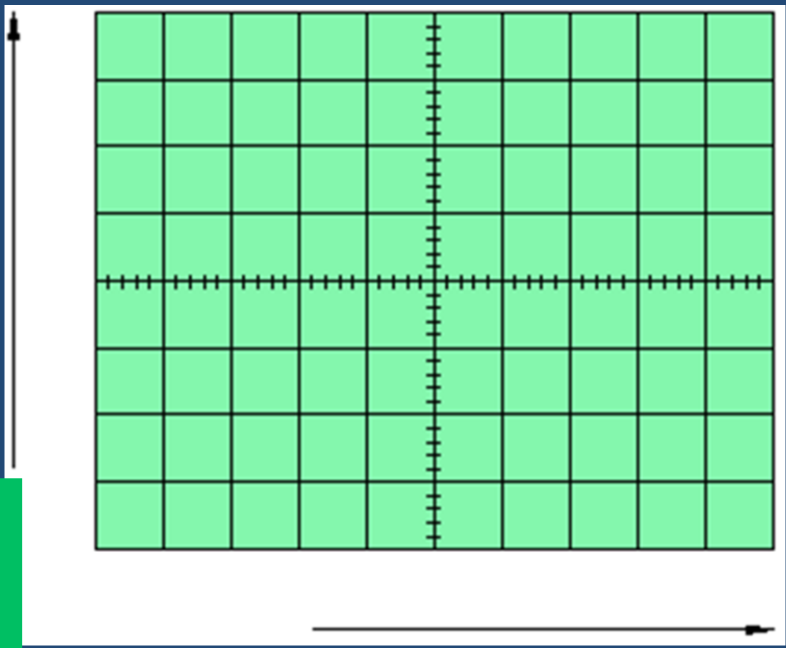
6) CAL. 0.5V/2V TERMINAL

To calibrate the output with 0.5V/2V and 1 KHz rectangular wave (squarewave) or for calibrating probes

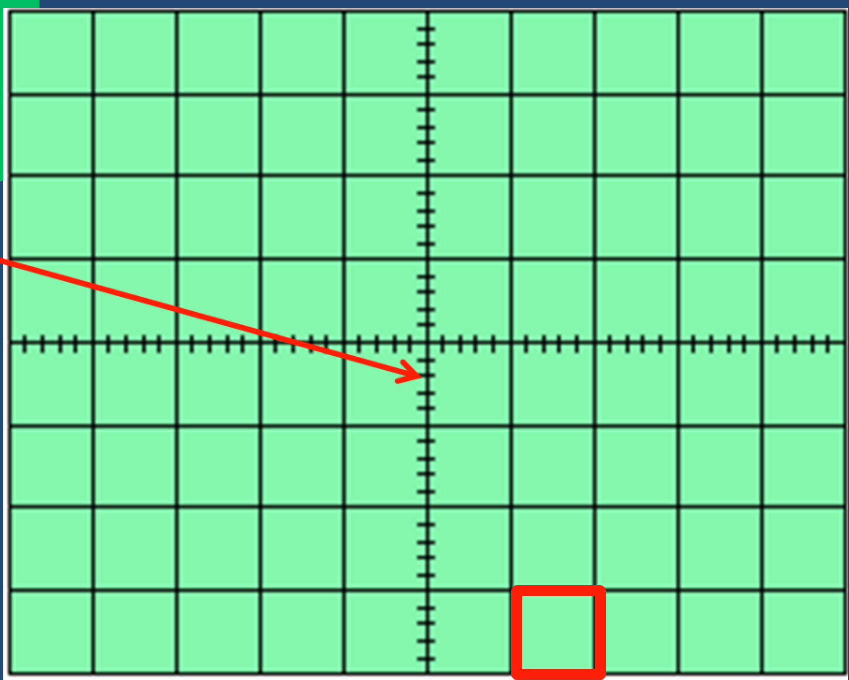
7) GND TERMINAL

This is a grounding terminal

MEASUREMENT TECHNIQUES



The graticule is a grid of lines that serves as a scale when making time and amplitude measurements with an oscilloscope.

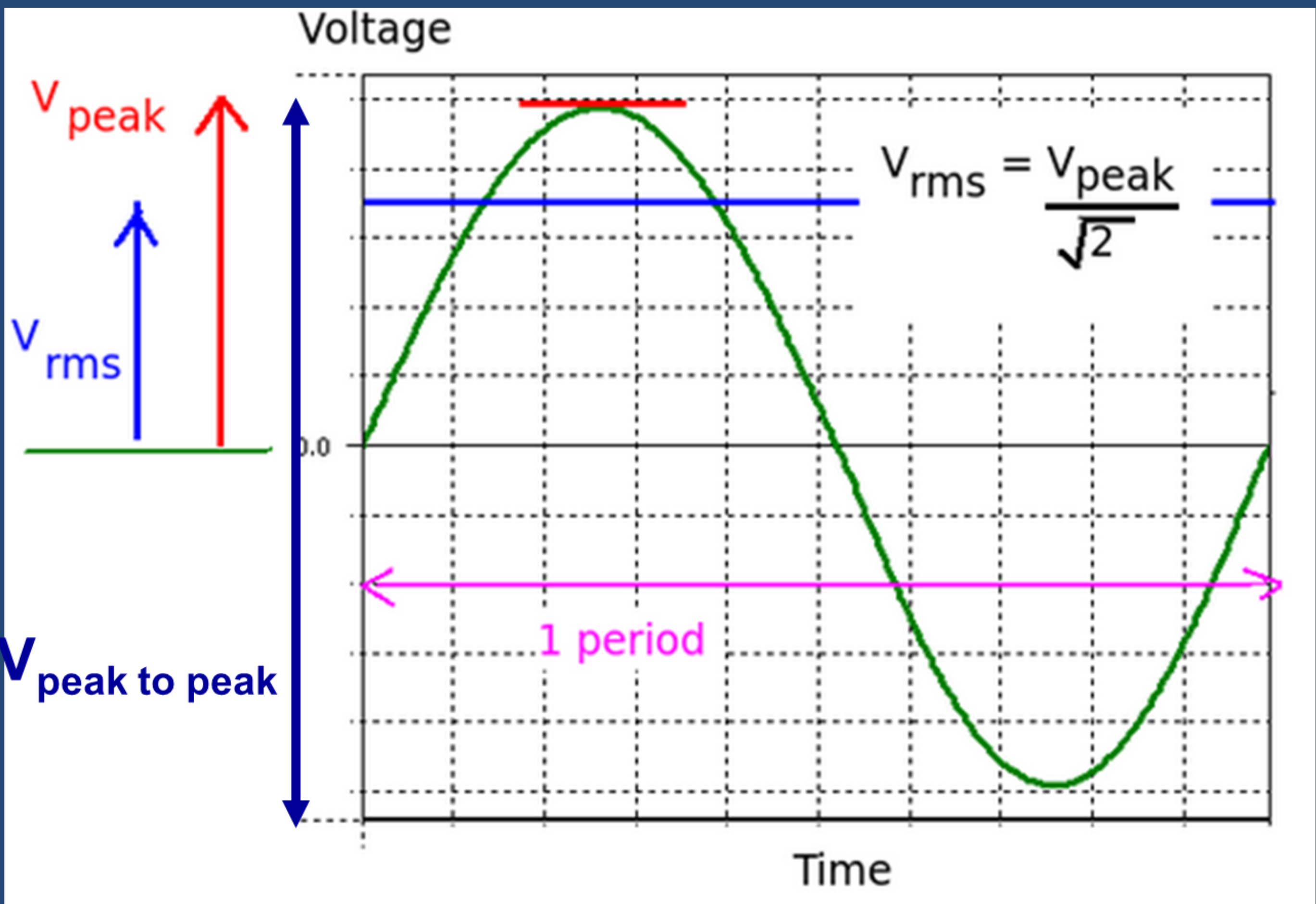


Voltage and **time** is determined by using **grids** on the display each square on the grid is called a **division**.

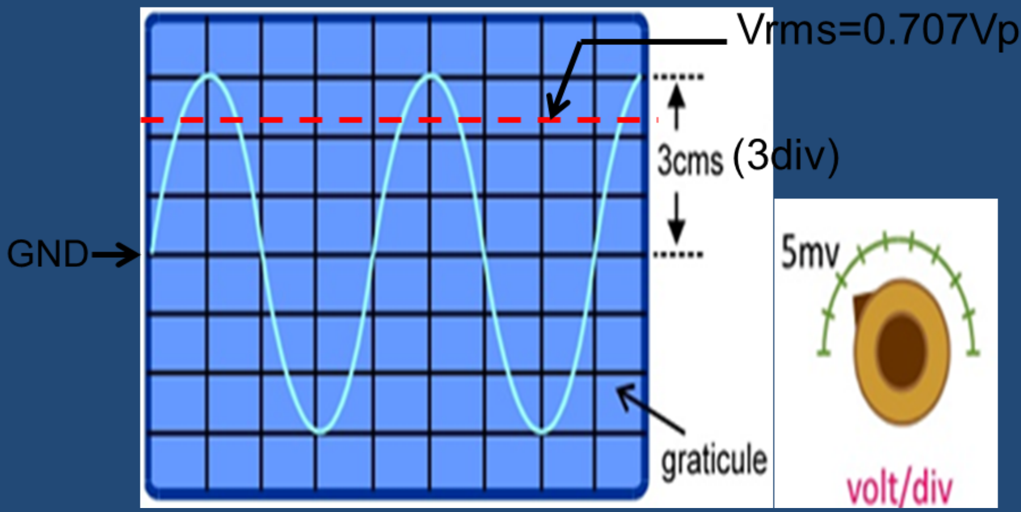
Division

AC MEASUREMENT

- voltage Peak-to-peak (Vp-p)
- Voltage Peak (Vp)
- Voltage RMS (root mean square, Vrms)
- Periodic Time (T)
- Frequency (f)
- Phase Shift (ϕ)



AMPLITUDE MEASUREMENT



voltage Peak-to-peak (Vp-p)

$$V_{p-p} = No.of\ Div_{(peak\ to\ peak)} \times \left({}^{volt}/_{div}\right)$$

$$V_{p-p} = [2 \times 3] \times (5mV)$$

$$V_{p-p} = 30mV$$

Voltage Peak (Vp)

$$V_p = No.of\ Div_{(peak\ )} \times \left({}^{volt}/_{div}\right)$$

$$V_p = (3) \times (5mV)$$

$$V_p = 15mV$$

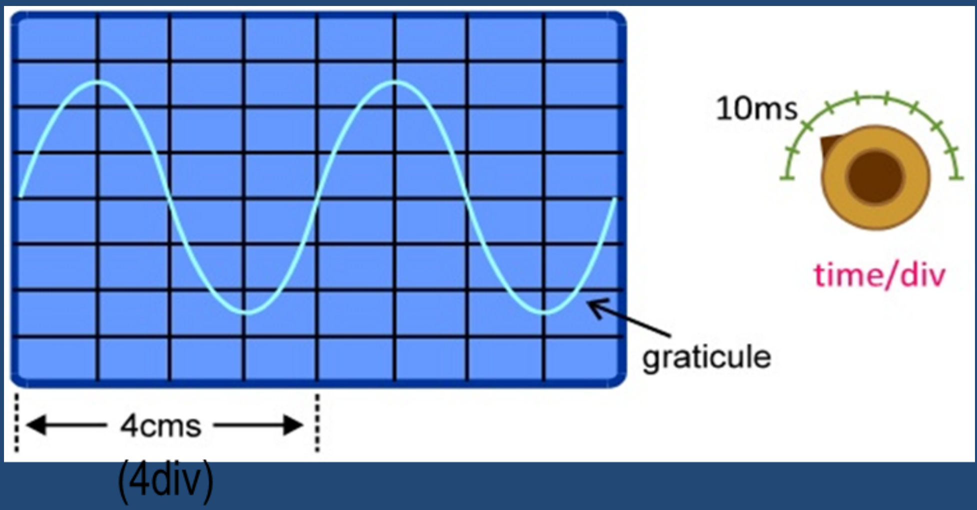
Voltage RMS (root mean square, Vrms)

$$V_{rms} = \frac{V_p}{\sqrt{2}} \quad = 0.707V_p$$

$$V_{rms} = 0.707(15mV)$$

$$V_{rms} = 10.605mV$$

FREQUENCY & TIME MEASUREMENT



Periodic Time (T)

$$Time, T = No.of\ Div_{(in\ 1\ cycle)} \times \left({}^{time}/_{div} \right)$$

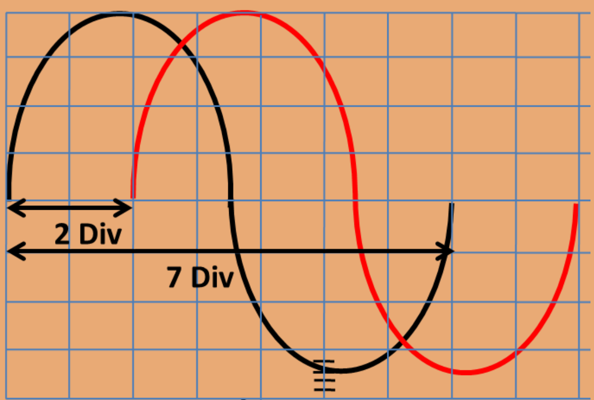
$$Time, T = 4 \times (10ms)$$

$$Time, T = 40ms$$

Frequency (f)

$$Frequency, f = \frac{1}{T}$$

Phase Shift

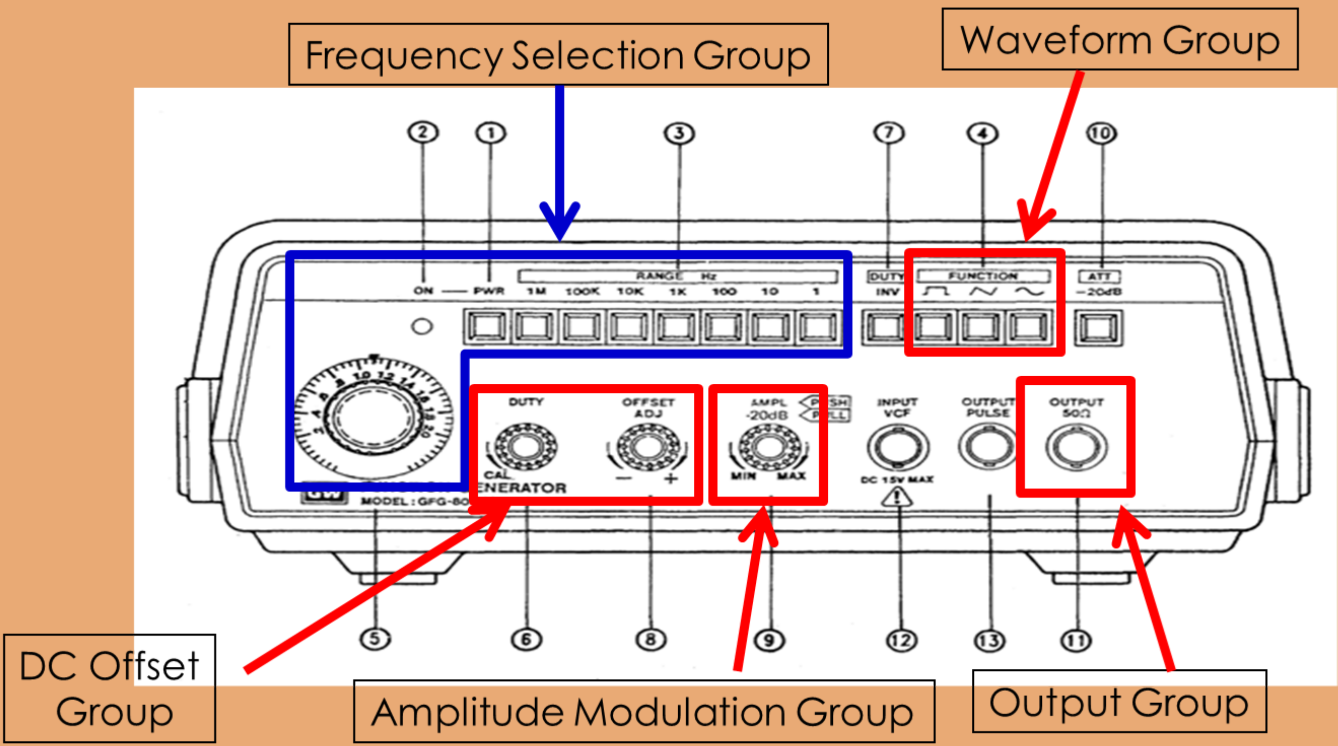


$$\theta = \frac{\Delta t}{One\ cycle\ distance} \times 360^0$$

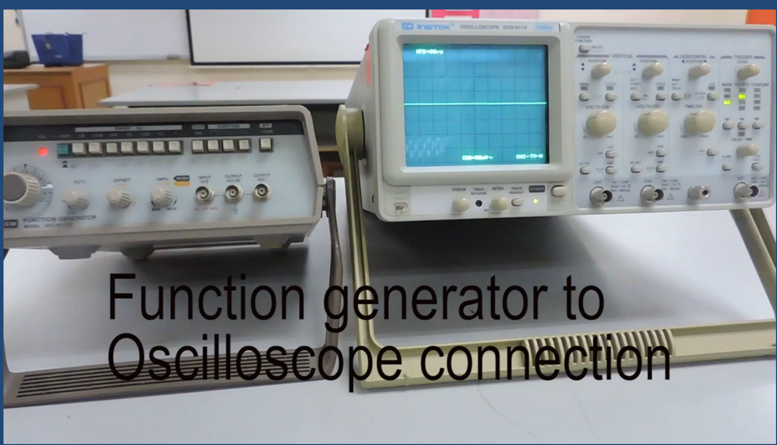
$$\theta = \frac{2}{7} \times 360^0 = 102.86^0$$

BASIC FUNCTION OF SIGNAL GENERATOR

Front panel of a signal generator



Connection between Osciloscope with Signal Genarator



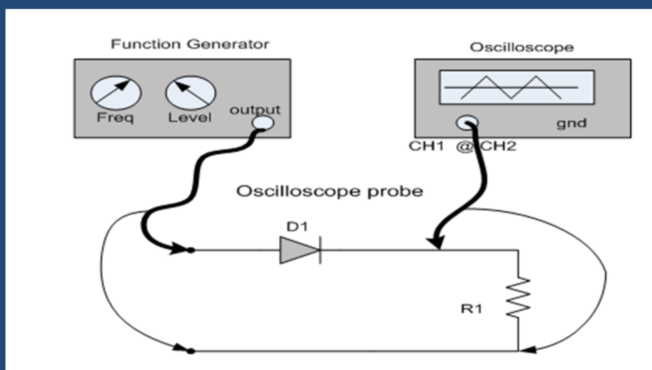


Figure 3.19: Connection to measure a signal in circuit

FUNCTION BUTTON FOR SIGNAL GENERATOR

1 Power Switch

The power switch applies power to the function generator.

2 Power On Indicator

- A light emitting diode (LED) is used to indicate when power is applied to the function generator.

3 Frequency Selection Group

To get the desire frequency, frequency selector must be multiply with frequency range

4 Waveform Group

- Waveform Selector
  - To choose type of waveforms
  - Either sine wave, rectangular or triangle

5 Amplitude Modulation Group

Amplitude Knob
To increase the amplitude of signal, this button should be adjust.

FUNCTION BUTTON FOR SIGNAL GENERATOR

6

DC OFFset Group

Consist of
1)Offset ADJ
2)Duty Control

7

Output Group

Consist of
1)Output 50 ohm squarewave,trianglewave,sinewave,BNC connector

Waveform Group

8

Consist of:
Waveform selector
-To choose type of waveform
-Either sine wave, rectangular or triangle wave

9

Sweep Group

-sweep is used to set the frequency output
-It could be swept up or down in frequency using wave

TUTORIAL 3

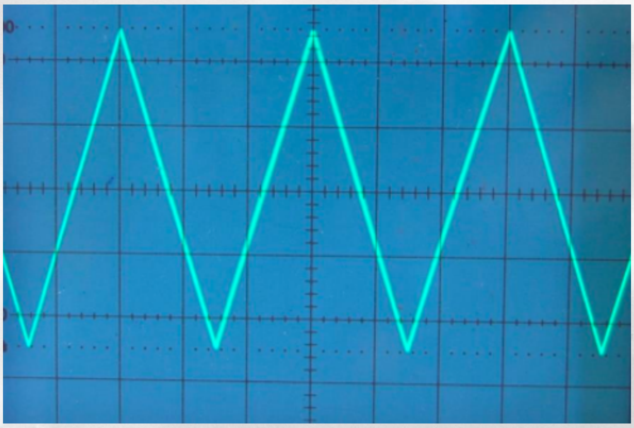


Figure 3.1

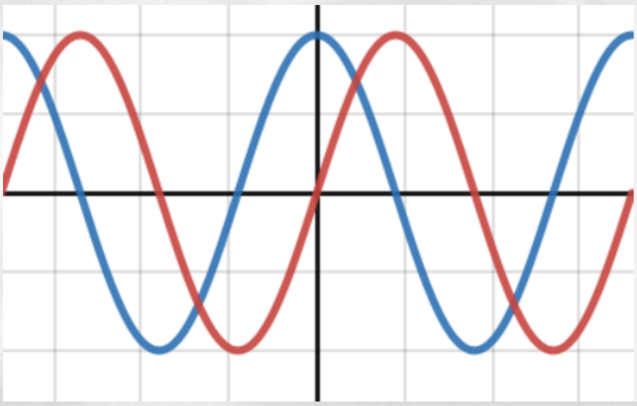
Given V/div=2V and T/div=2ms, from the graph in figure 3.1, calculate:

a) Peak to peak volatge (Vpp)
b)Peak volatge (Vp)
c)Periodic Time (T)
d)Frequency (F)
e)Root mean square voltage (Vrms)

Figure 3.2

Given V/div=0.5V and T/div=0.5ms, from the graph in figure 3.2, calculate:

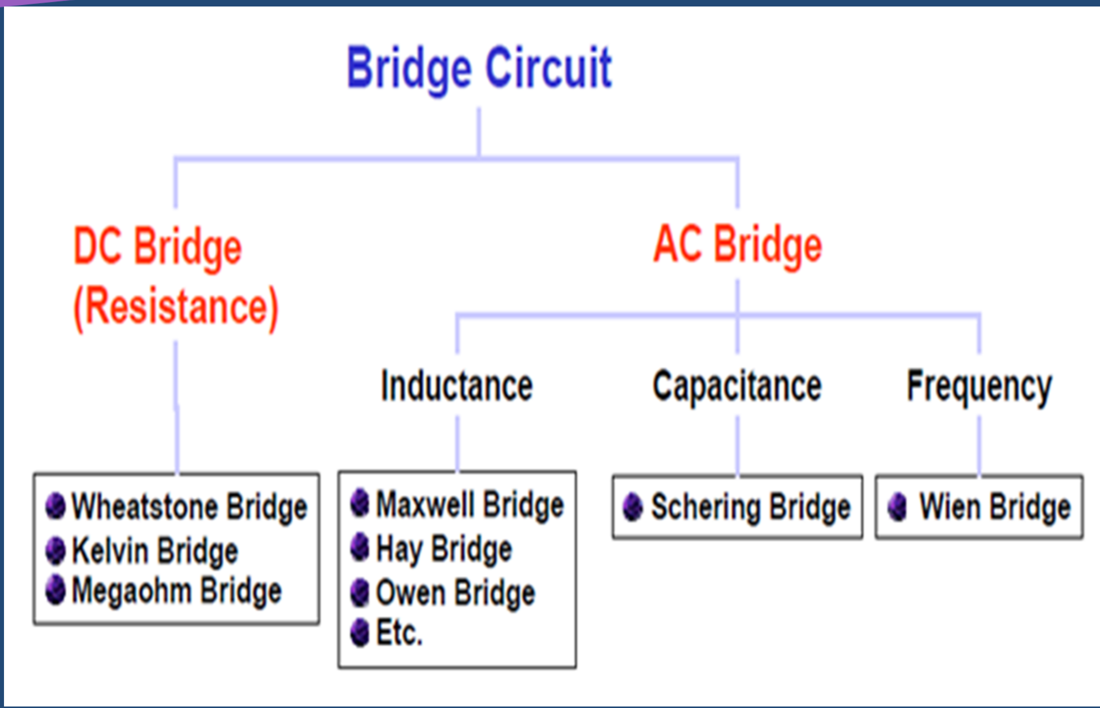
a) Peak to peak voltage (Vpp)
b)Peak volatge (Vp)
c)Periodic Time (T)
d)Frequency (F)
e)Root mean square voltage (Vrms)

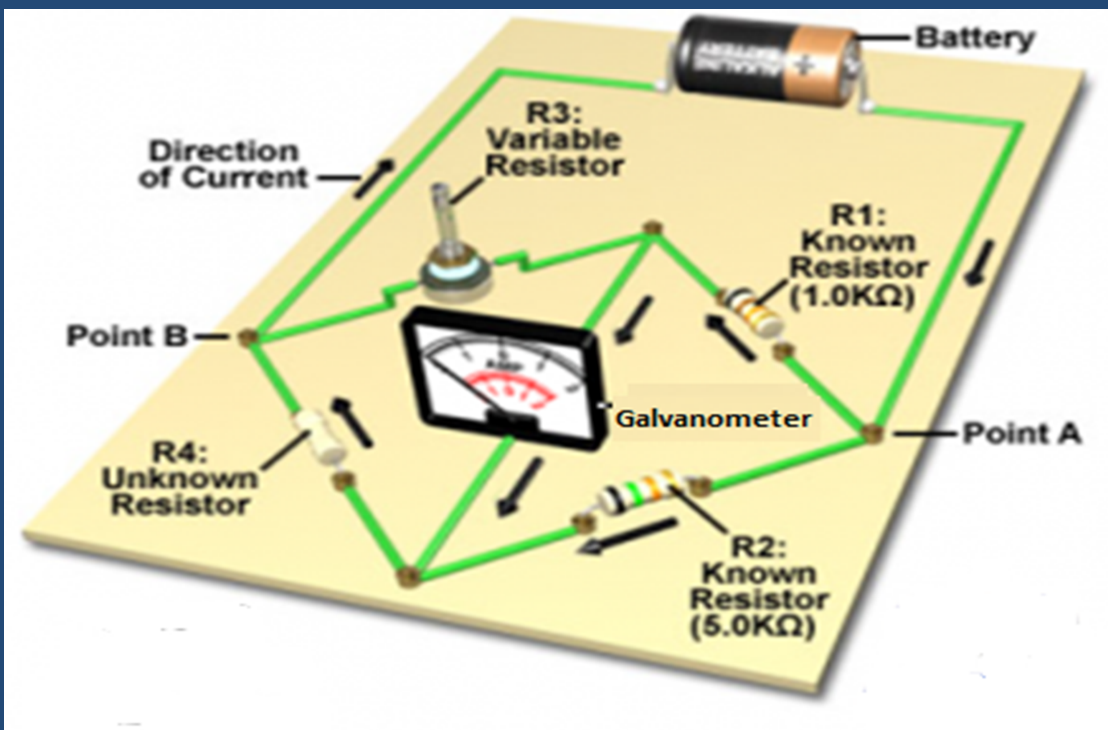


Given V/div=1V and T/div=2ms, from the graph in figure 3.2, calculate:

a) Peak to peak volatge (Vpp)
b)Peak voltage (Vp)
c)Periodic Time (T)
d)Frequency (F)
e)Root mean square voltage (Vrms)
d)Phase angle

04. DC BRIDGE

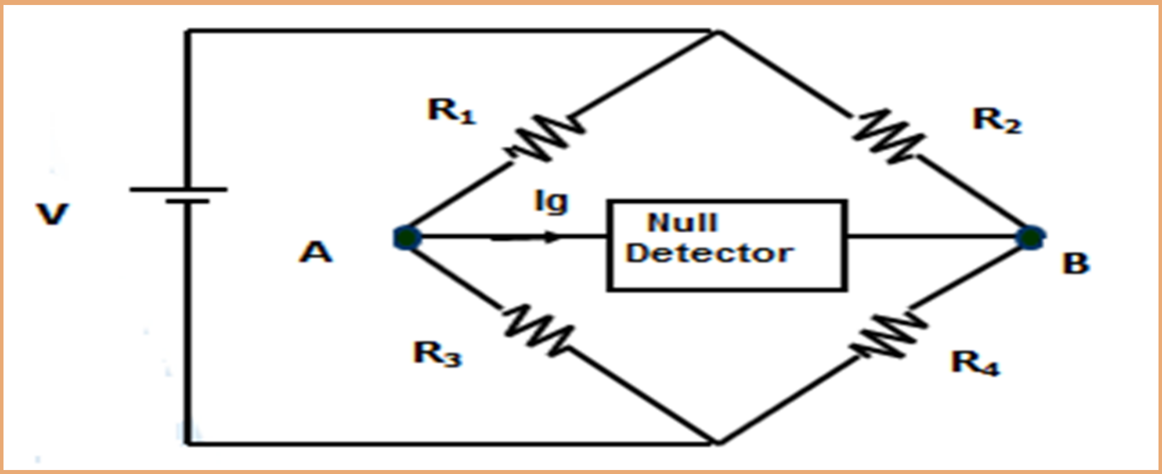

Bridge Circuit
DC Bridge (Resistance)
AC Bridge
Inductance
Capacitance
Frequency
Wheatstone Bridge
Kelvin Bridge
Megaohm Bridge
Maxwell Bridge
Hay Bridge
Owen Bridge
Etc.
Schering Bridge
Wien Bridge

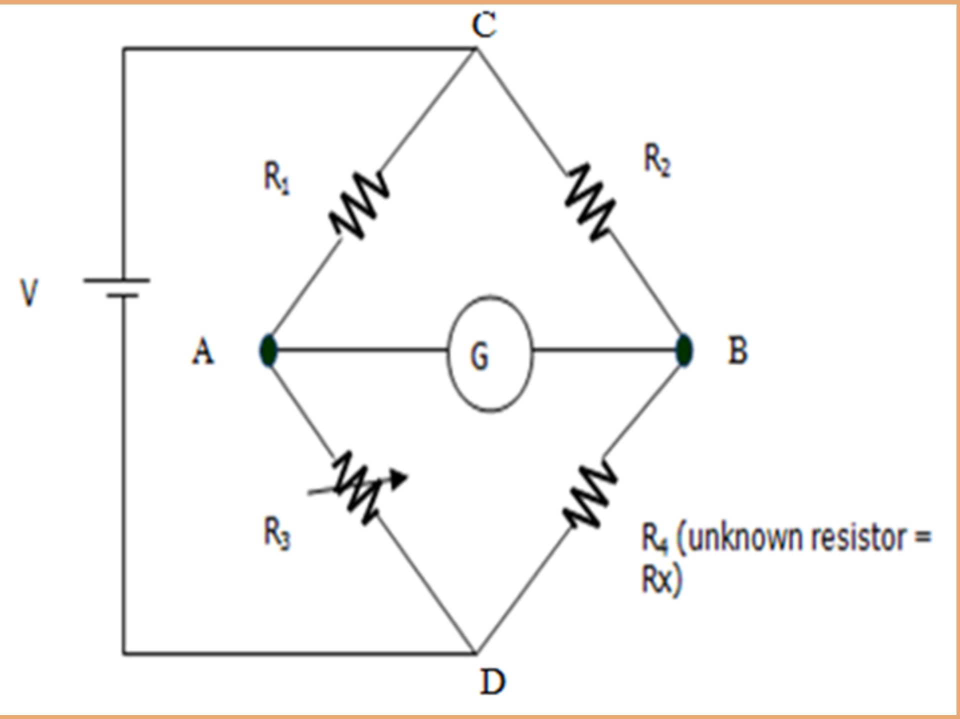

Battery
R3: Variable Resistor
Direction of Current
R1: Known Resistor (1.0KΩ)
Point B
Galvanometer
Point A
R4: Unknown Resistor
R2: Known Resistor (5.0KΩ)

THE CONCEPT OF DC WHEATSTONE BRIDGE

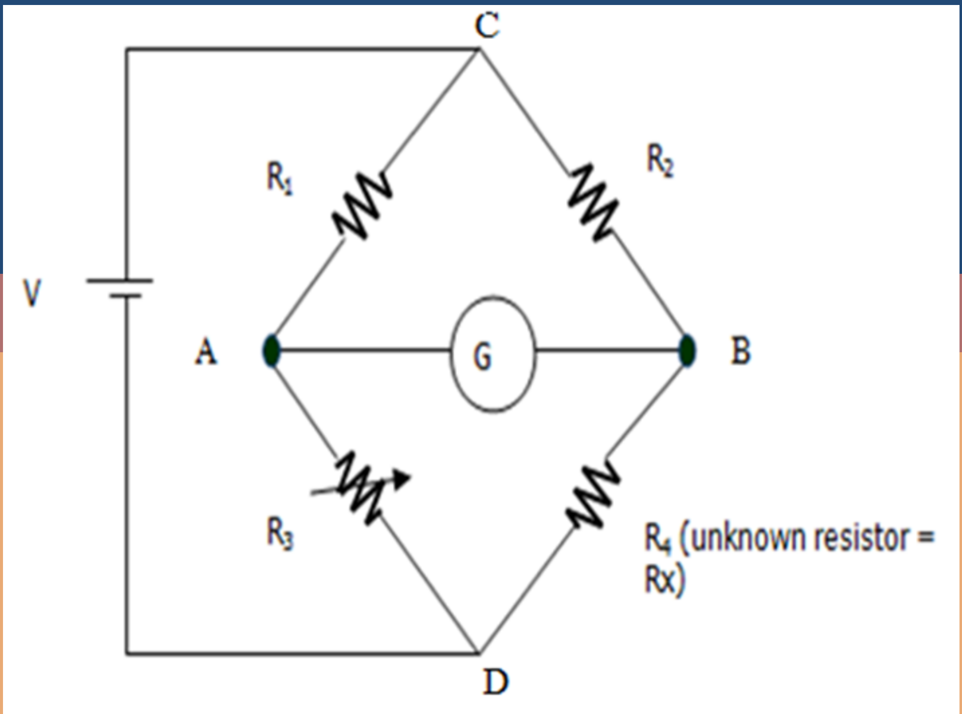
1 Bridge circuit generally refers to a circuit in which a load is connected between two levels of resistors. The load is call a null detector.

2 When the voltage between point A is equal to the voltage between point B, the null detector(Galvanometer) will indicate zero.That means no current flow through the load (Ig=0) . This condition shows that the bridge is in balance.





THE WHEATSTONE BRIDGE SCHEMATIC DIAGRAM



1. The battery (v) is connected between C and B while the galvanometer (G) is connected between A and B.

2. R4 is the unknown resistor and will known as Rx.

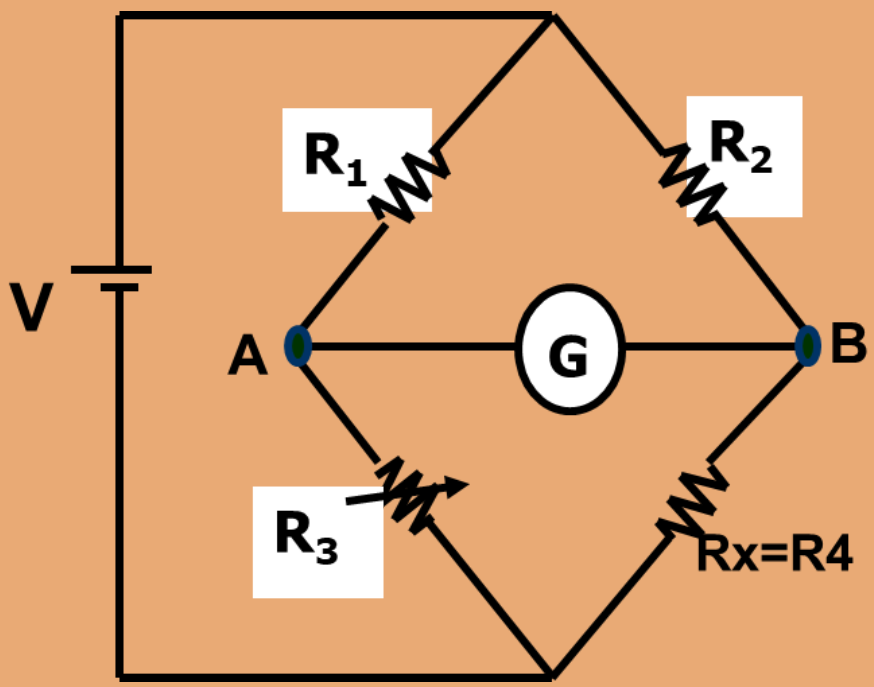
3. R1, R2 and R3 are resistors of known resistance and the resistance of R3 is adjustable

4. The arms consisting the resistances R1 and R2 are called ratio arms. The arm consisting the standard known resistance R3 is called standard arm.

5. The resistance R4 is the unknown resistance to be measured. The battery is connected between C and D while galvanometer is connected between A and B.

6. Now the bridge as two series circuits: one consisting of resistors R1 and R3 and the other consisting of R2 and R4. The two series circuits are connected in parallel with each other.

DERIVATION EQUATION FOR DC WHEATSTONE BRIDGE



$$V_{AB} = V_{AC}$$

$$\left(\frac{R_1}{R_1+R_3}\right)E = \left(\frac{R_2}{R_2+R_4}\right)E$$

$$\frac{R_1}{R_1+R_3} = \frac{R_2}{R_2+R_4}$$

$$R_1(R_2+R_4) = R_2(R_1+R_3)$$

$$R_1R_2 + R_1R_4 = R_2R_1 + R_2R_3$$

$$R_1R_4 = R_2R_3$$

$$R_4 = \frac{R_2R_3}{R_1}$$

TUTORIAL 4

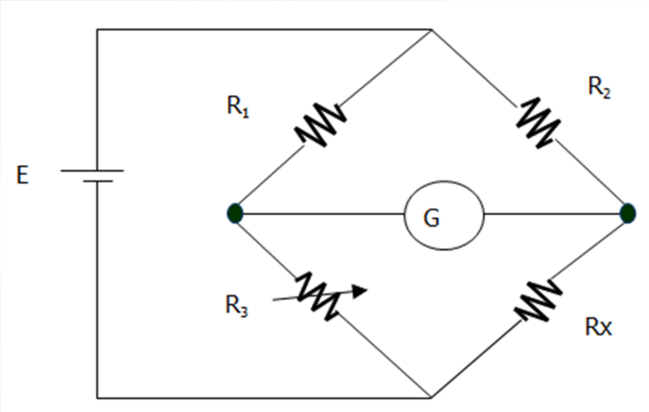


Figure 4.1

Figure 4.1 shows a diagram of a Wheatstone Bridge with R1=100Ω R2=1000Ω and R3=200Ω.
Determine the value for Rx, if the bridge is in balance condition.

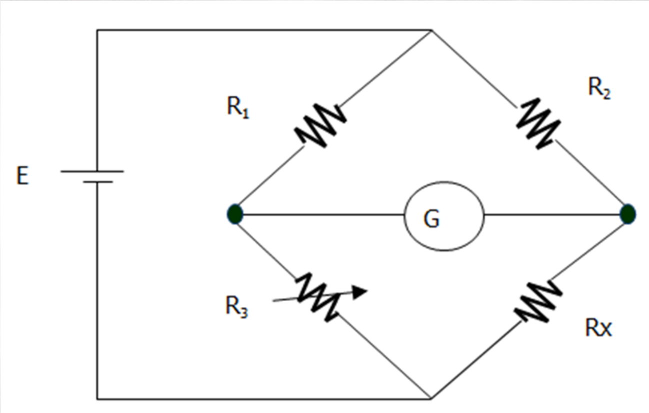


Figure 4.2

Figure 4.2 shows a diagram of a Wheatstone Bridge with R1=50Ω, R2=2R1 and R3=100Ω. Determine the value for Rx, if the bridge is in balance condition.

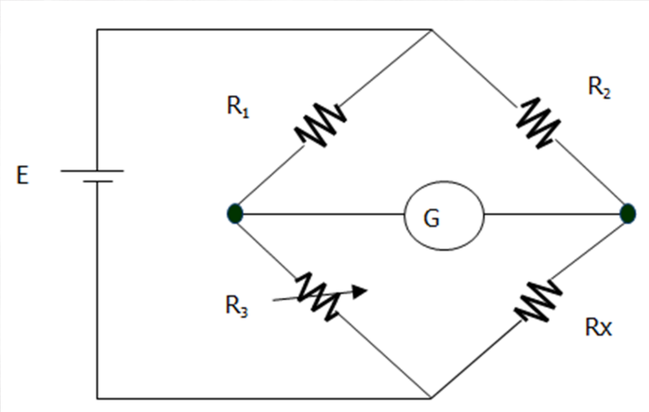


Figure 4.3

From the Figure 4.3, derive the equation for Rx if the bridge is in balance condition.

05. POWER METERS

INTRODUCTION OF POWER METER

- Power in an electric circuit is the product (multiplication) of voltage and current, so any meter designed to measure power must account for both of these variables.
- Power is measured in watts (or kilowatts).
- Power meter is a meter to measure the amount of electric power used.
- There are many kind of Power Meters such as Wattmeter, KWH meter, Clamp meter etc (see figure 5.1).

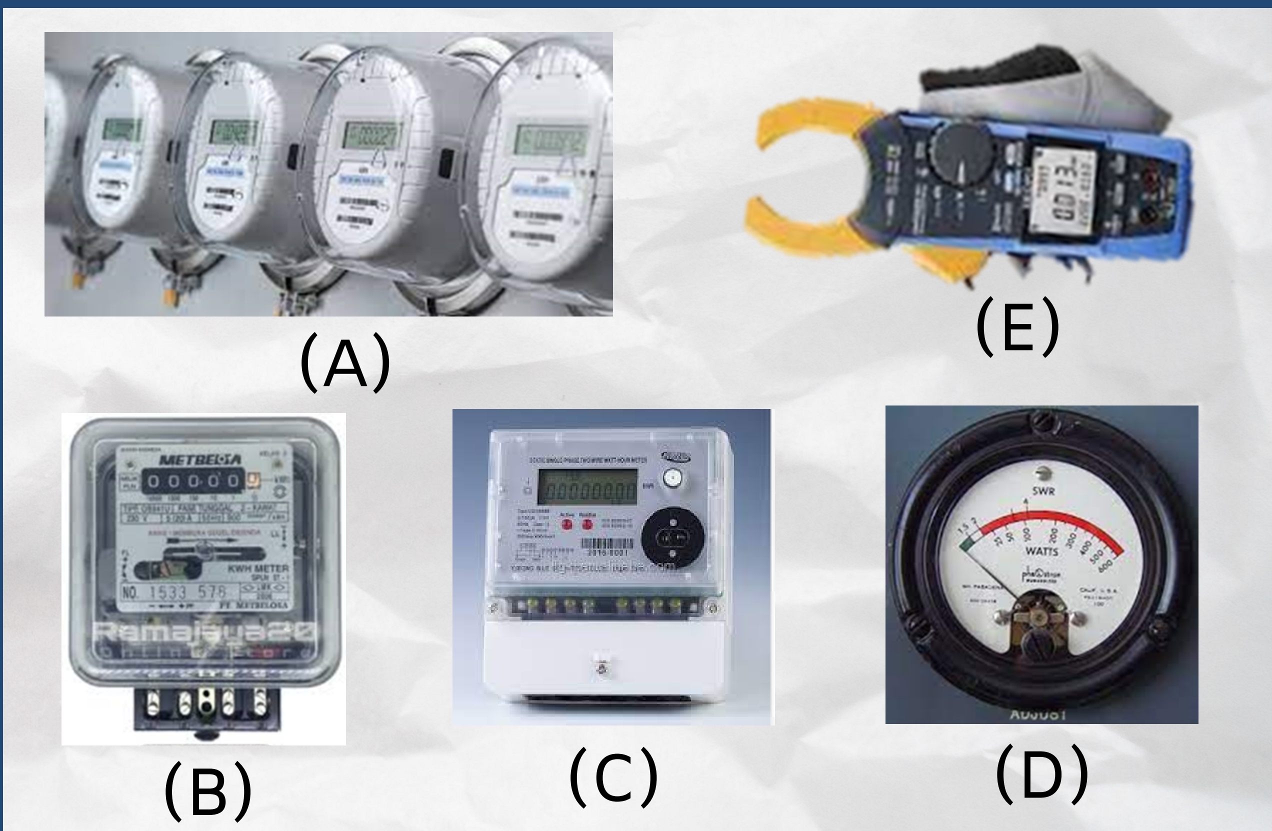


Figure 5.1 : Type of Power Meter (A,B,C-KWH meter, D- Wattmeter, E- Clamp meter).

Three equations for power in circuits that are collectively known as Watt's law are:

$$P = IV \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

Example 1:

What power is dissipated by a heater that draws 12 A of current from a 120 V supply?

Solution:

The most direct solution is to substitute into

$$\begin{aligned} P &= IV \\ &= (12\ \text{A})(120\ \text{V}) \\ &= 1440\ \text{W} \end{aligned}$$

Example 2:

What power is dissipated in a 27 W resistor is the current is 0.135 A?

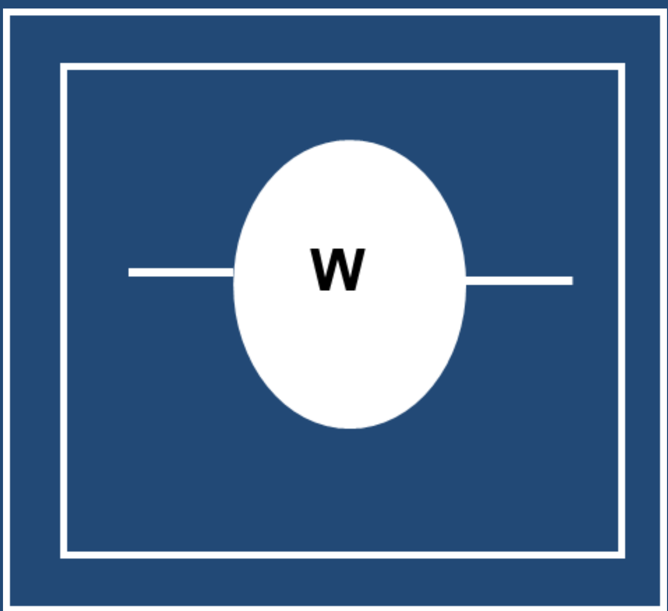
Solution:

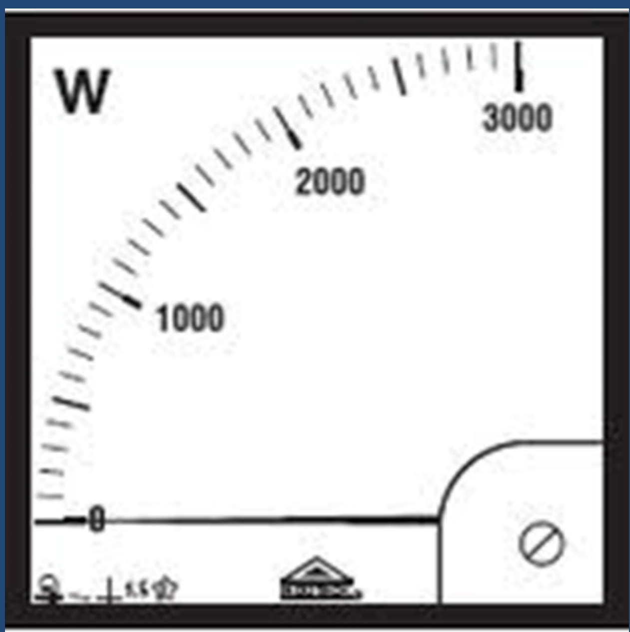
Given that you know the resistance and current, substitute the values into P =I 2R.

$$\begin{aligned} P &= I^2R \\ &= (0.135\ \text{A})^2(27\ \Omega) \\ &= 0.49\ \text{W} \end{aligned}$$

ANALOGUE WATT METER

SYMBOL OF ANALOGUE WATT METER





THE PRINCIPLES OF ANALOUGE WATTMETER

A

The traditional analog wattmeter is an electrodynamics instrument.

B

The device consists of: a pair of fixed coils, (known as current coils)

C

a movable coil (known as the potential / voltage coil)

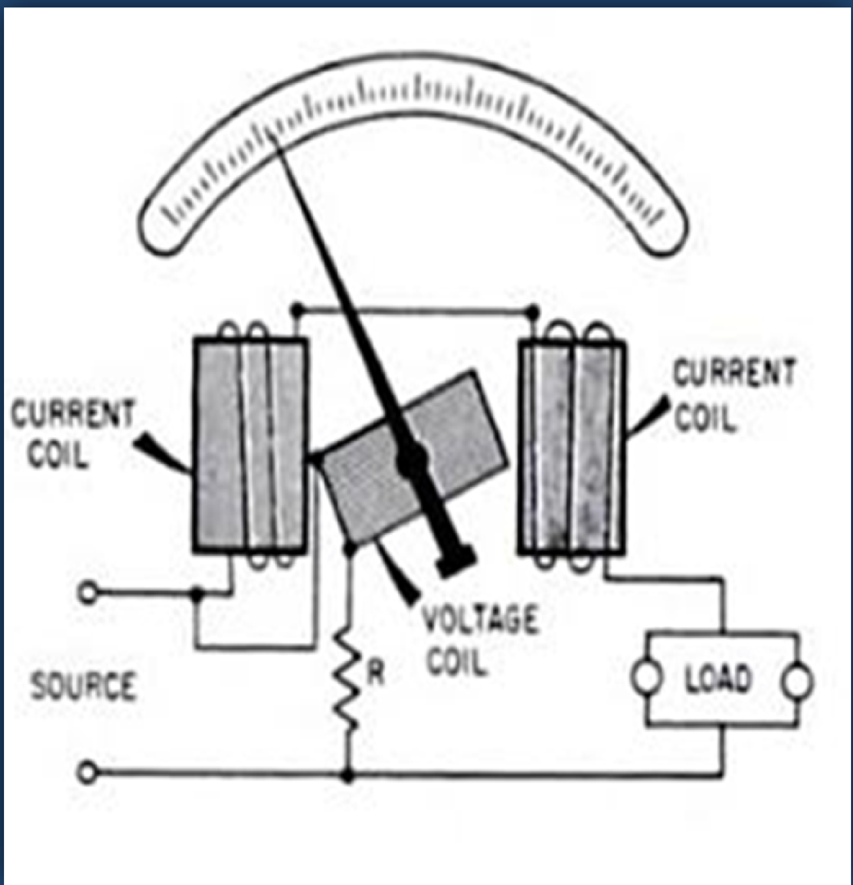


Figure 5.2: A simplified electrodynamic wattmeter circuit.

THE PRINCIPLES OF ANALOUGE WATTMETER

The current coils connected in series with the circuit, while the voltage coil is connected in parallel with the circuit.

When a current flowing through the current coil generates an electromagnetic field around the coil.

The voltage coil carries a needle that moves over a scale to indicate the measurement

The voltage coil of the wattmeter generally has a high-resistance resistor connected in series with it (to reduce the current that flows through it)

The result of this arrangement is that on a dc circuit, the deflection of the needle is proportional to both the current and the voltage thus conforming to the equation P =VI

MECHANISM OF WATTMETER

VOLTAGE COIL

Voltage coil
Many turns of fine wire encased in plastic connected in parallel with load.

CURRENT COIL

Three turns of thick wire, connected in series with load.

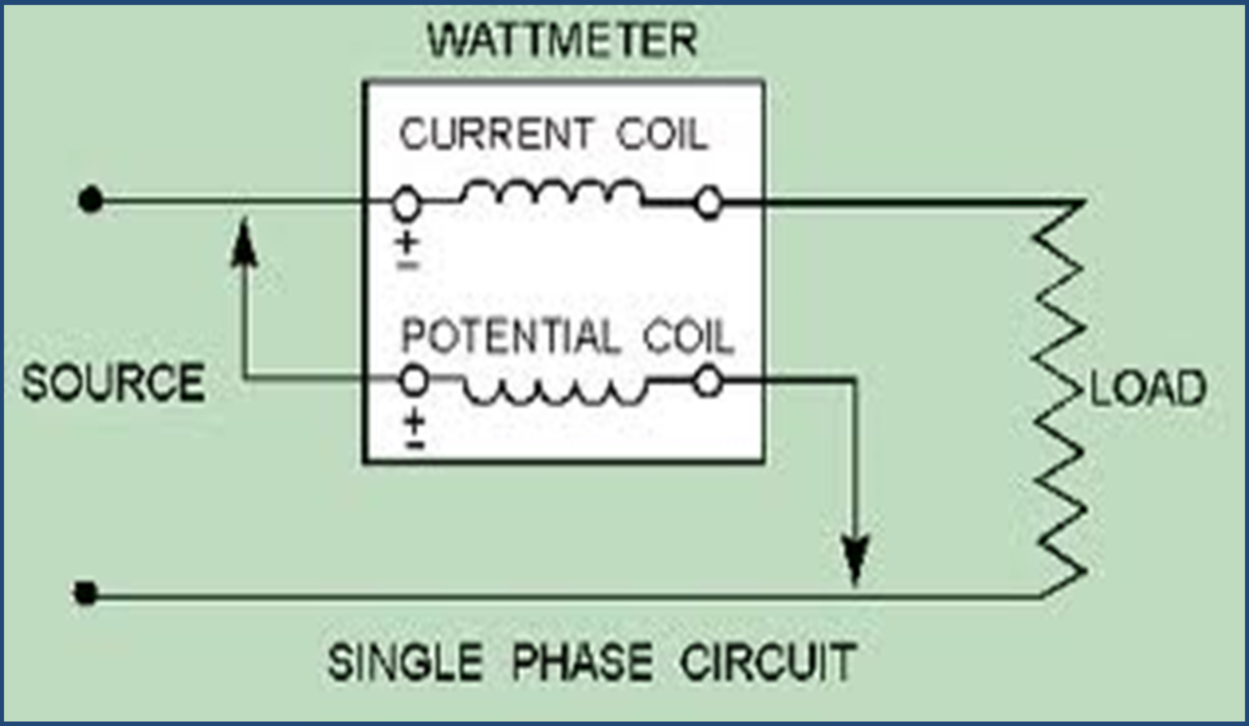


Figure 5.3 : The connection a wattmeter in a single phase circuit.

KILOWATT HOUR METER

CONSTRUCTION OF KWH METER

A single phase induction type energy meter consists of driving system, moving system, braking system and registering system.

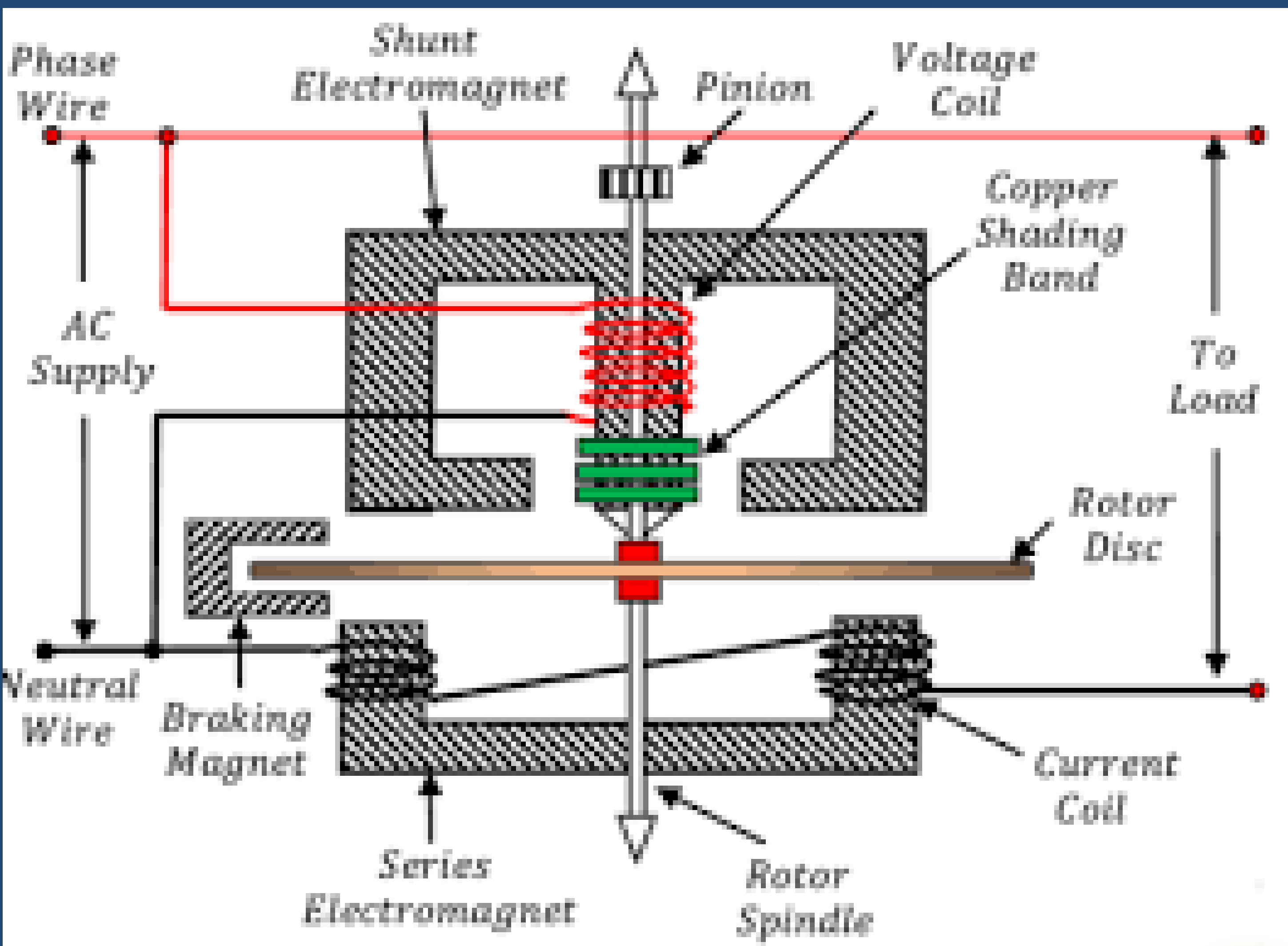


Figure 5.4 : Construction of Kilowatt-hour meter

A) DRIVING SYSTEM

- Driving system of the energy meter consists of two silicon steel laminated electromagnets.
- Referring figure 5.4,the electromagnet M1 is called the series magnet or current coil (CC) and the electromagnet M2 is called the shunt magnet or voltage coil (VC) .
- The current coil carries a coil consisting of a few turns of thick wire and it is connected in series with the circuit. The load current flows through this coil.
- The voltage coil carries a coil consisting many turns of thin wire and it is connected across the supply.

B) MOVING SYSTEM

- The moving system consists of a thin aluminum disc mounted on a spindle and is placed in the air gap between the series and the shunt magnets.
- It cuts the flux of both the magnet forces are produced by the fluxes of M1 & M2 .
- Both these forces act on the disc. These two forces constitute a deflecting torque.

C) BRAKING SYSTEM

- The braking system consists of a permanent magnet called brake magnet.
- Provides necessary braking torque which opposes the motion of disc.

D) REGISTERING SYSTEM

- The disc spindle is connected to a counting mechanism this mechanism records a number which is proportional to the number of revolutions of the disc.
- The counter is calibrated to indicate

  the energy consumed directly in kilo watts-hour (KWH)

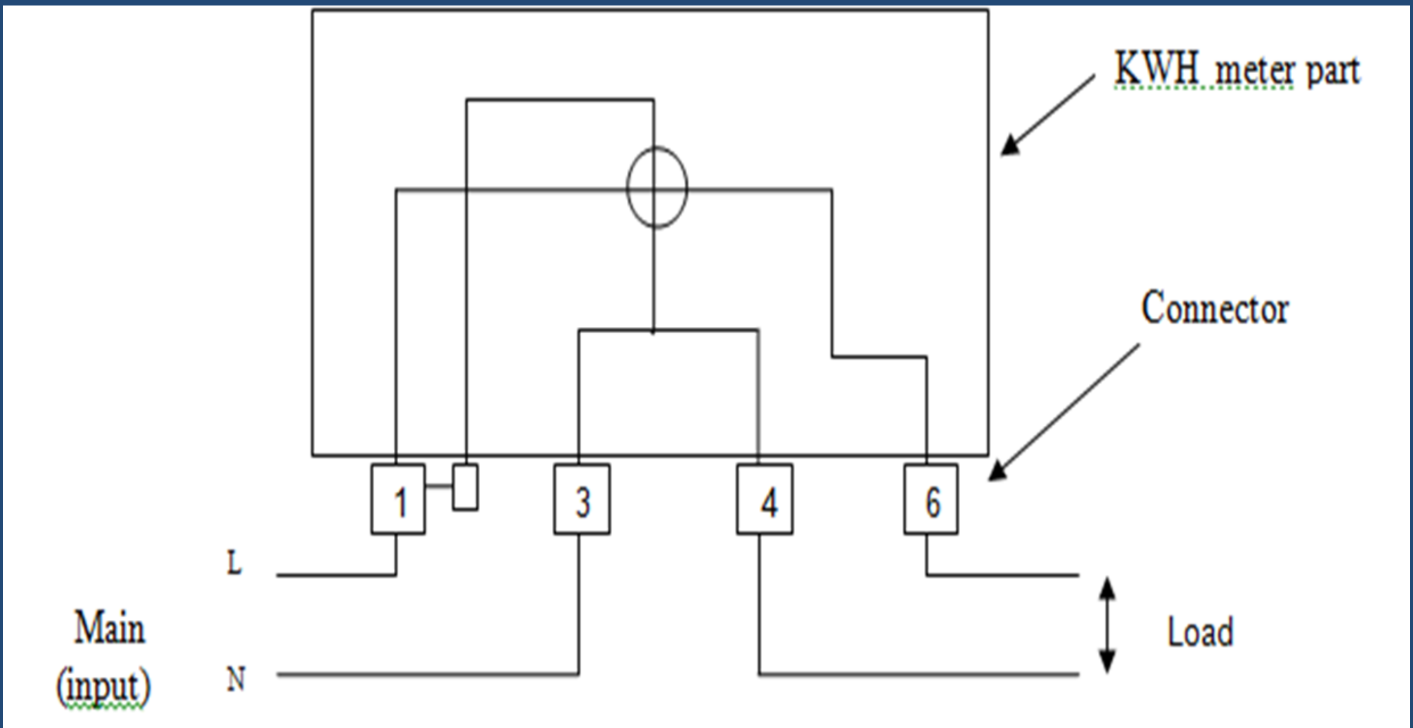


Figure 5.5 : Connection For Electrical Energy Measurement

BASIC PRINCIPLE OF ANALOGUE KWH METER

A

The Kilowatt-hour meter is an instrument for measuring the amount of electrical energy consumed by a residence, business, or an electrically powered device.

B

Kilowatt hour is most commonly known as a billing unit for energy delivered to consumers by electric utility.

C

In principle, the watt-hour meter is a small motor whose instantaneous speed is proportional to the power passing through it

D

Energy = Power x time (joules)

E

The total revolutions in a given time are proportional to the total energy or watt-hour, consumed during that time.

F

The current coil is connected in series with the line and the voltage coil is connected across the line.

G

Both coil are wound on a metal frame of special design, providing two magnetic circuits.

H

A light aluminums disk is suspended in the air gap of current coil field, which cause eddy currents flow in the disc

TUTORIAL 5

1. a. Draw the connection of Wattmeter for power measurement.

   b. Name THREE (3) mechanisms of electromechanical induction meter in watt-hour meter ?

2. Calculate the Power Consumption in the system with the voltage is 35.5V and the current is 1.25A.

3. A wattmeter is an instrument used to measure the electrical power. Draw then construction of a wattmeter.

4. A Kilo Watt Hour (kWh) meter is an instrument used to measure the amount of electrical energy. With the aid of suitable diagram, write briefly two system in the construction of kWh meter.

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