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Section A

17PWELE5087

5th Semester

Electrical Engineering Department

Electrical Measurments And Instrumentations.

Lab 1

01/oct/19

To find the unknown capacitance using three voltmeters method.

Apparatus

Auto transformer
Rheostate
Voltmeters
Capacitor
Resistor
Connecting wires.

Autotransformer has only one winding; a portion of which is used as primary and secondary. It can step up and step down the given voltage.

Rheostate is a variable resistor.

Error = Measured value − True value

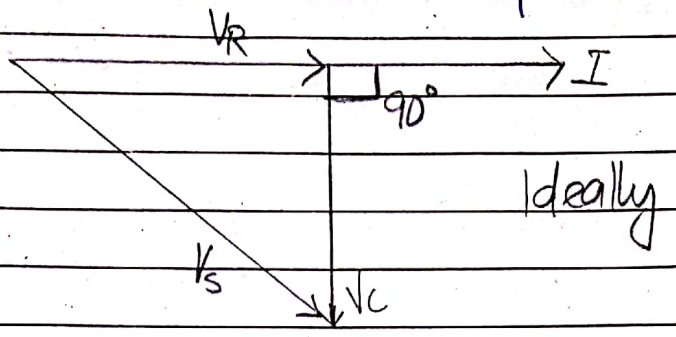
Limiting error or **Relative static error**

$$= \frac{\text{Error}}{\text{True value}} \times 100.$$

Accuracy = 100% − L.E / R.S.E

Apply KVL

$V_S = V_R + V_C$ (phasor Sum)



Practically there will be some resistance of the capacitor; so the angle would not be exactly 90°, it would be θ.

$V_C \sin\theta = I \cdot X_C$

$V_R = I \cdot R \Rightarrow I = V_R/R$

$X_C = 1/\omega C$

$V_C \sin\theta = \frac{V_R}{R} \cdot \frac{1}{2\pi f C}$

$$\Rightarrow C = \frac{V_R}{V_C \sin\theta \cdot R \cdot 2\pi f}$$

Procedure

The circuit is designed according to the given circuit diagram.

We determine V_R, V_S and V_C with the help of voltmeters.

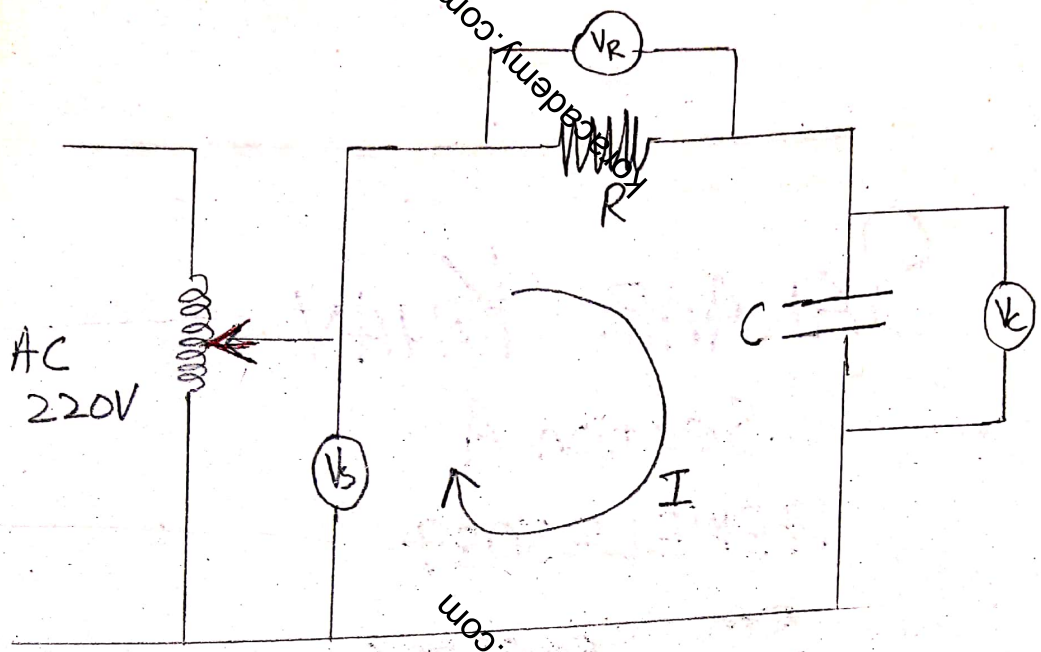
To draw the diagram select a suitable scale. Draw V_R along the reference axis ie I.
At the tail of V_R place compass needle and draw an arc of length V_C.
At the head of V_R, place the compass needle to make an arc of length V_S.

Find the angle b/w reference axis and V_C.
Put the value of θ in the formula for e to determine its value.

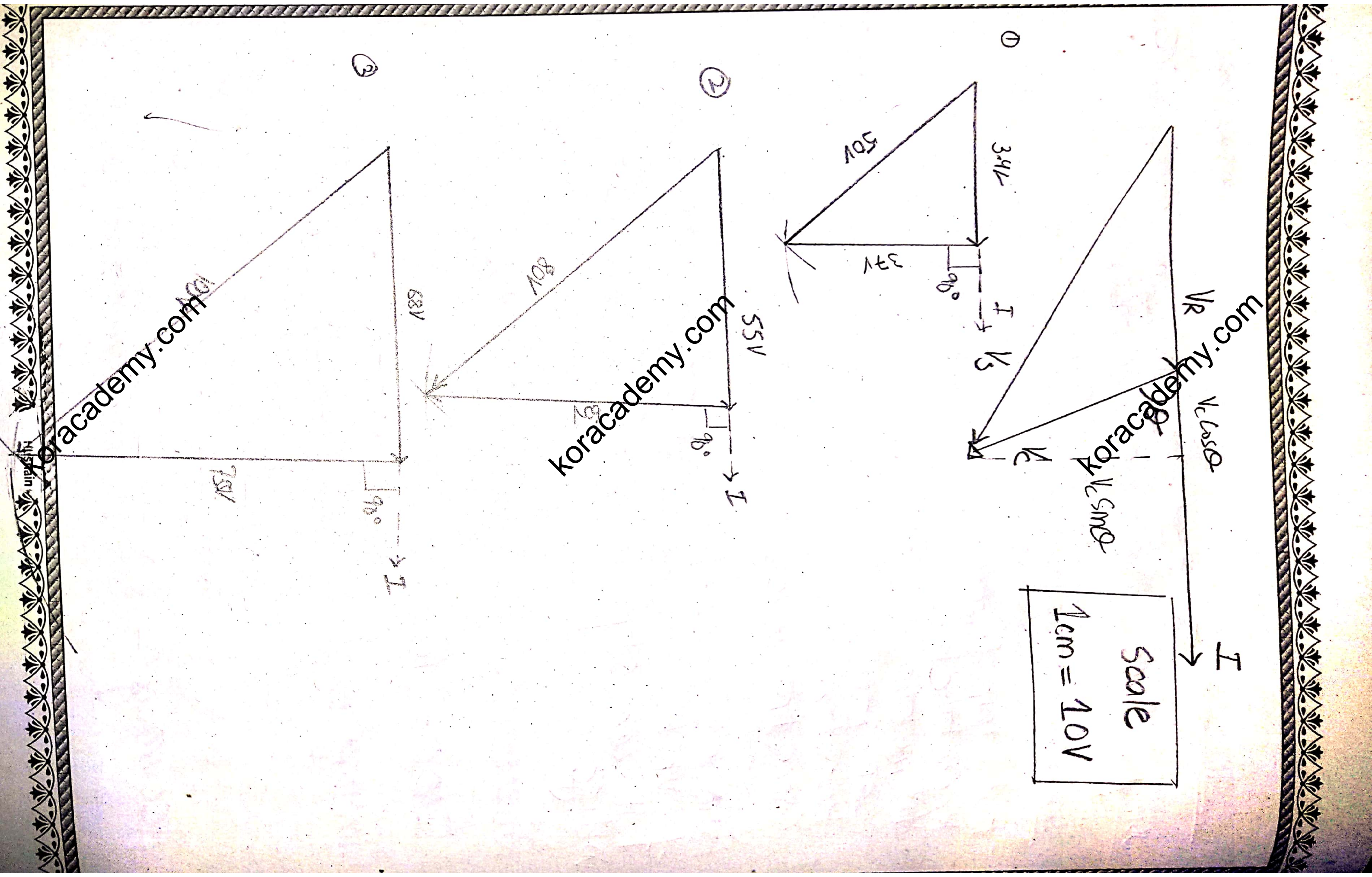
Precautions

The circuit must be in accordance with the circuit diagram.
Select a proper scale.
Take readings carefully.
Draw the diagrams neat and clean.

7/10



S.No	V_S (V)	V_R (V)	V_C (V)	θ	C	Error
1	50	34.07	37.7	90°	10μF	0
2	80	54.6	60.3	90°	10μF	0
3	100	68.5	75.7	90°	10μF	0



Lab 2

08/10/19

To measure unknown inductance using three voltmeters method.

Apparatus

Auto Transformer
Rheostate
Voltmeters
~~Capacitor~~
Resistor
Connecting wires.
Inductor.

Theory

Apply KVL $\Rightarrow V_S = V_R + V_L$.

The phasor diagram is shown in figure (a) which shows that ideally V_L leads the current axis by an angle of exactly 90°.

But practically there is some internal resistance of the inductor due to which this angle is not 90°.

It is less than 90°, say θ. figure (b).

So we have two components of V_L;

(i) The resistive component: $V_L \cos\theta$

(ii) The inductive component: $V_L \sin\theta$.

$$V_L \sin\theta = I X_L$$

$$\Rightarrow V_L \sin\theta = \frac{V_R}{R} \times 2\pi f L$$

$$L = \frac{V_L \sin\theta \, R}{2\pi f V_R}$$

Procedure

The circuit is designed according to the diagram. We determine V_s, V_R and V_L through voltmeters.

V_R is drawn along the reference axis ie I. At the tail of V_R place the compass needle and draw an arc of length V_L. At the head of V_R place compass to draw an arc of length V_s.

Find the angle b/w the reference axis and V_L.

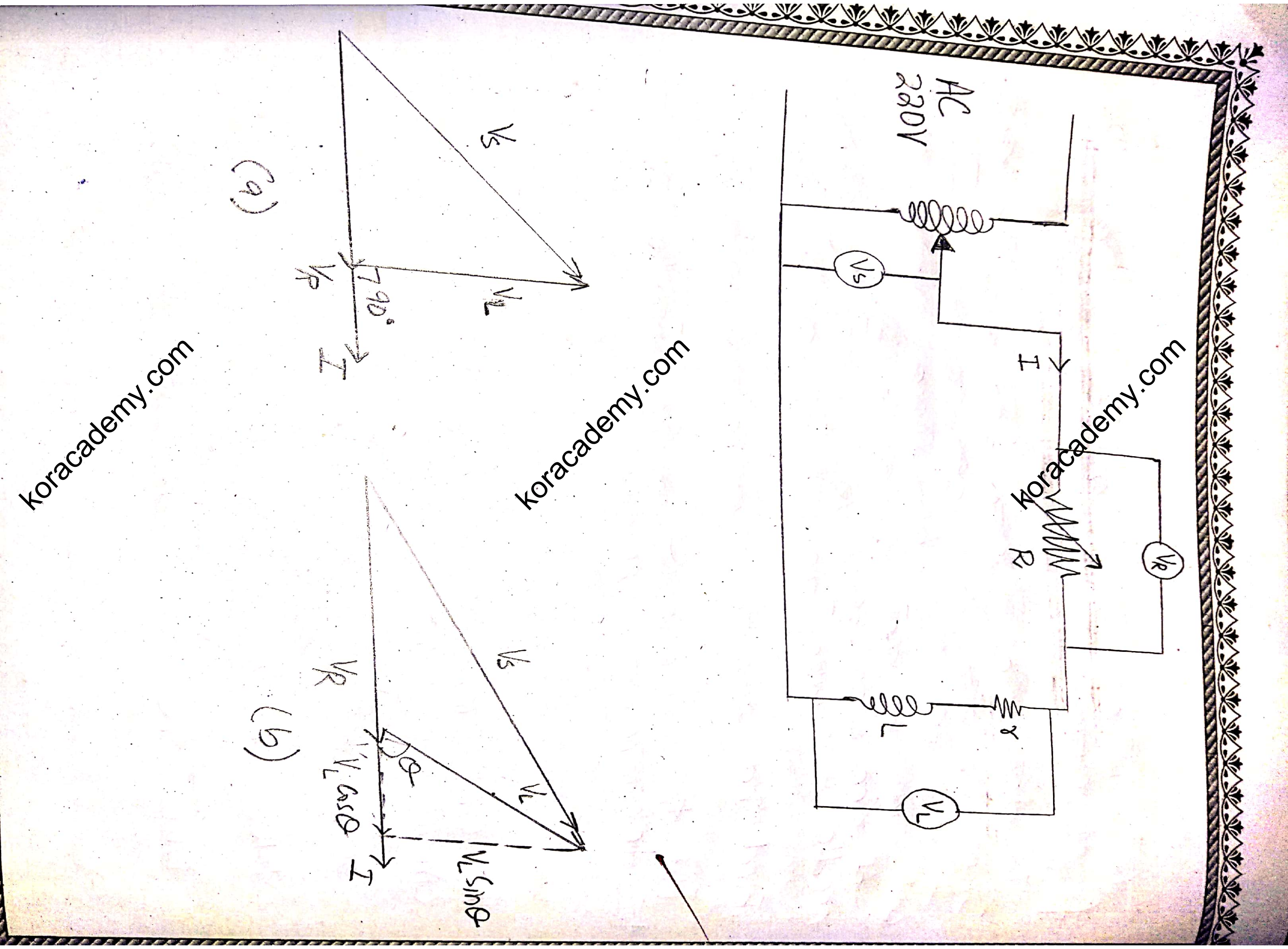
Put the angle θ in the above formula of L to calculate the unknown inductance.

6/10

Phasor Diagram

Precautions

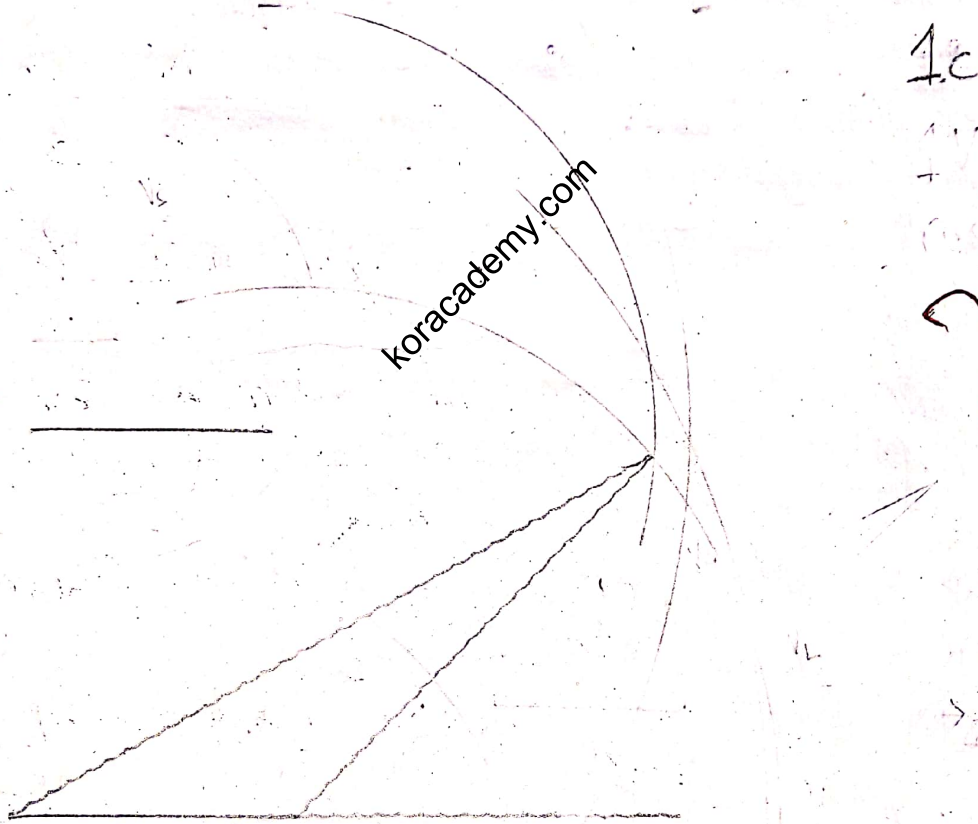
→ The circuit must be correct and in accordance with the circuit diagram.
→ Select a suitable scale.
→ Take readings accurately.
→ Draw the diagrams neat and clean.

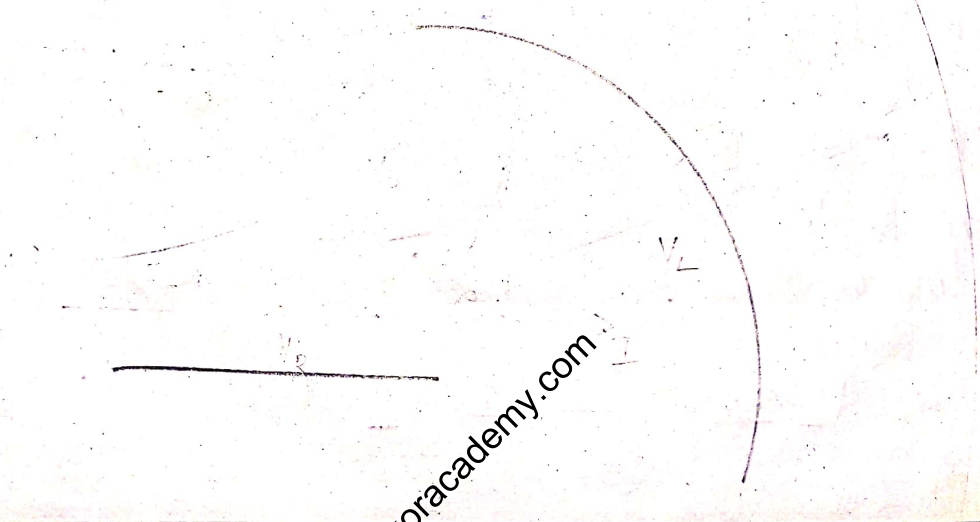


SNO	R(Ω)	V_S(V)	V_R(V)	V_L(V)	θ	L	L_{mean}	L_{True}	E = L_m − L_T	% R.E
1	47Ω	8.85	3.1	5.2			0.11	0.111		
2		10.2	3.81	6.42	43°		0.13			
3		11.7	4.3	4.3			0.14			

Scale

1 cm → 1V





Lab 3

15/10/19

To learn some useful functions of calculator.

1) Unit Conversions

To convert b/w any two units press shift and 8 of the calculator.
Now it asks number b/w 01 and 40.
The table of unit conversion is given on the cover of calculator from where you chose your desired.
eg to convert inches to centimeter, you have to press 1.

2) Constants

To know the value of any scientific constant, press shift and 7. Now calculator asks for number b/w 01 and 40.
eg To know the value of permitivity of free space; press shift 7 and then 32.

$$\Rightarrow \quad \varepsilon_0 = 8.854187817 \times 10^{-12}$$

3) Table generation

To generate a table, go to MODE and press 7. Now it asks for value of function.
eg we have $f(x) = e^x + 2x + 3x^2 + 5$
and $x = 1 - 9$.
When you type the function press equal. Calculator asks for the starting, ending

and step values which in our case;
Start = 1 end = 9 step = 1
So a table has been generated.

X	f(X)
1	12.718
2	28.389
↓	
9	8863

4) Equation Solving

eg we need to solve;

$$2x + 5y = 3$$
$$9x - 2y = -5$$

Go to MODE and select 5 ie the equation mode
Now select the type of equation depending on your need eg here we need to select 1.
Give it the values of a, b and c and calculate gives you result;
ie $x = 0.3875$ $y = -0.7555$

You can also solve an equation in COMP MODE.
Go to mode and select 1.
Now type the equation eg $2^{2^x} = 1.2$
This encircled equals is typed by the equal command by alpha plus CALC.

When you type the equation, give it the solve command by SHIFT + CALC.
It asks for an initial value say 0 and gives you the result.

$X = -1.92668$

5) COMPLEX

Press MODE and then 2, so calculator will go to complex mode.
In polar form $(2\angle 45°)$ convert it to rectangular form
Press 2 then shift then (−) and write 45, so

$2\angle 45° = \sqrt{2} + \sqrt{2}i$

6. Matrix

Go the MODE then 6. It asks for matrix let 1 ie MAT A, now it asks the size eg 1 ie 3×3 Enter all the values.

let $A = \begin{bmatrix} 1 & 2 & 4 \\ 3 & 6 & 5 \\ 7 & 6 & 8 \end{bmatrix}$ $B = \begin{bmatrix} 2 & 3 & 4 \\ 1 & 6 & 0 \\ 1 & 9 & 2 \end{bmatrix}$

eg we need A×B.
Now we need to enter matrix B. Press ON then Shift then 4. Press 2 for Data, now enter matrix B so enter 2. Again 3×3 so 1, again Enter values Press shift then 4, Now 3, X, Shift 4 now 4, = the so MAT A X MAT B displays. Press answer is

$\begin{bmatrix} 9 & 51 & 12 \\ 17 & 90 & 22 \\ 28 & 129 & 44 \end{bmatrix}$

For inverse of matrix:

↳ matrix mode → 1 → enter values → ON button → shift → 4 → 3 → x^{-1} → =

so $A^{-1} = \begin{bmatrix} -0.34 & -0.192 & 0.25 \\ -0.196 & 0.352 & -0.125 \\ -0.425 & -0.192 & 0 \end{bmatrix}$

7. STAT

Enter STAT mode by MODE then 3, then select type of function. To input data

shift 1 (STAT) 2 (DATA) for L-R of two variable when we i/p the data then to obtain statistical value press AC then shift 4 (STAT)

(2) to find the sum which we need (to D

(4) (5) number of item mean $\bar{x}$, σ_n (S.D).

Regression coefficient.

(6) Min value and Max value

Let we have some data to find SD.

STAT MODE

shift + MODE 4

1 for ON.

MOD STAT 3.

x	freq
2	50
3	30
4	10
5	15

$\sigma_n + 2$ 1.0695

9/10

CASIO fx 570ES PLUS

Natural V.P.A-M

SETUP

SHIFT Alpha ▲ REPLAY ▶ MODE ON

SOLVE= $\frac{d}{dx}$: $\int_a^b$ CALC $x!$ x^{-1} $\log_{\square}\square$

$\frac{\square}{\square}$ $\sqrt[3]{\square}$ x^3 DEC $\sqrt{\square}$ HEX $10^{\square}$ BIN $e^{\square}$ OCT

$\frac{\blacksquare}{\square}$ $\sqrt{\blacksquare}$ x^2 $x^{\square}$ log ln

[<] [A] ← [B] Abs [C] $\sin^{-1}$ [D] $\cos^{-1}$ [E] $\tan^{-1}$ [F]

(-) °''' hyp sin cos tan

STO ← i % ? X $a^{b/c}$ $\frac{d}{c}y$ M-M

RCL ENG ( ) S⇔D M+

CONST CONV CLR INS OFF

7 8 9 DEL AC

MATRIX VECTOR nPr nCr

4 5 6 × ÷

STAT [CMPLX] [BASE] Pol Rec

1 2 3 + −

Rnd Ran# RanInt π e DRG ▶

0 • $\times 10^x$ Ans =

Lab 4

22/10/19

To measure the single phase power using three voltmeters method.

Apparatus

Auto transformer
Rheostatte (variable resistor)
Inductive load.
Voltmeters.

Theory

Apply KVL $V_s = V_R + V_L$

$\theta \rightarrow$ power factor angle.

$$V_s^2 = V_L^2 \sin^2\theta + (V_R + V_L \cos\theta)^2$$

$$V_s^2 = V_L^2 \sin^2\theta + V_R^2 + V_L^2 \cos^2\theta + 2V_R V_L \cos\theta$$

$$V_s^2 = V_L^2 (\sin^2\theta + \cos^2\theta) + V_R^2 + 2V_R V_L \cos\theta$$

$$V_s^2 - V_L^2 - V_R^2 = 2V_R V_L \cos\theta$$

$$\boxed{\cos\theta = \frac{V_s^2 - V_L^2 - V_R^2}{2V_R V_L}} \rightarrow \text{Power factor of the load.}$$

For Power

$$P = V_L I \cos\theta$$

$$P = V_L \left(\frac{V_R}{R}\right)\left(\frac{V_s^2 - V_L^2 - V_R^2}{2V_R V_L}\right)$$

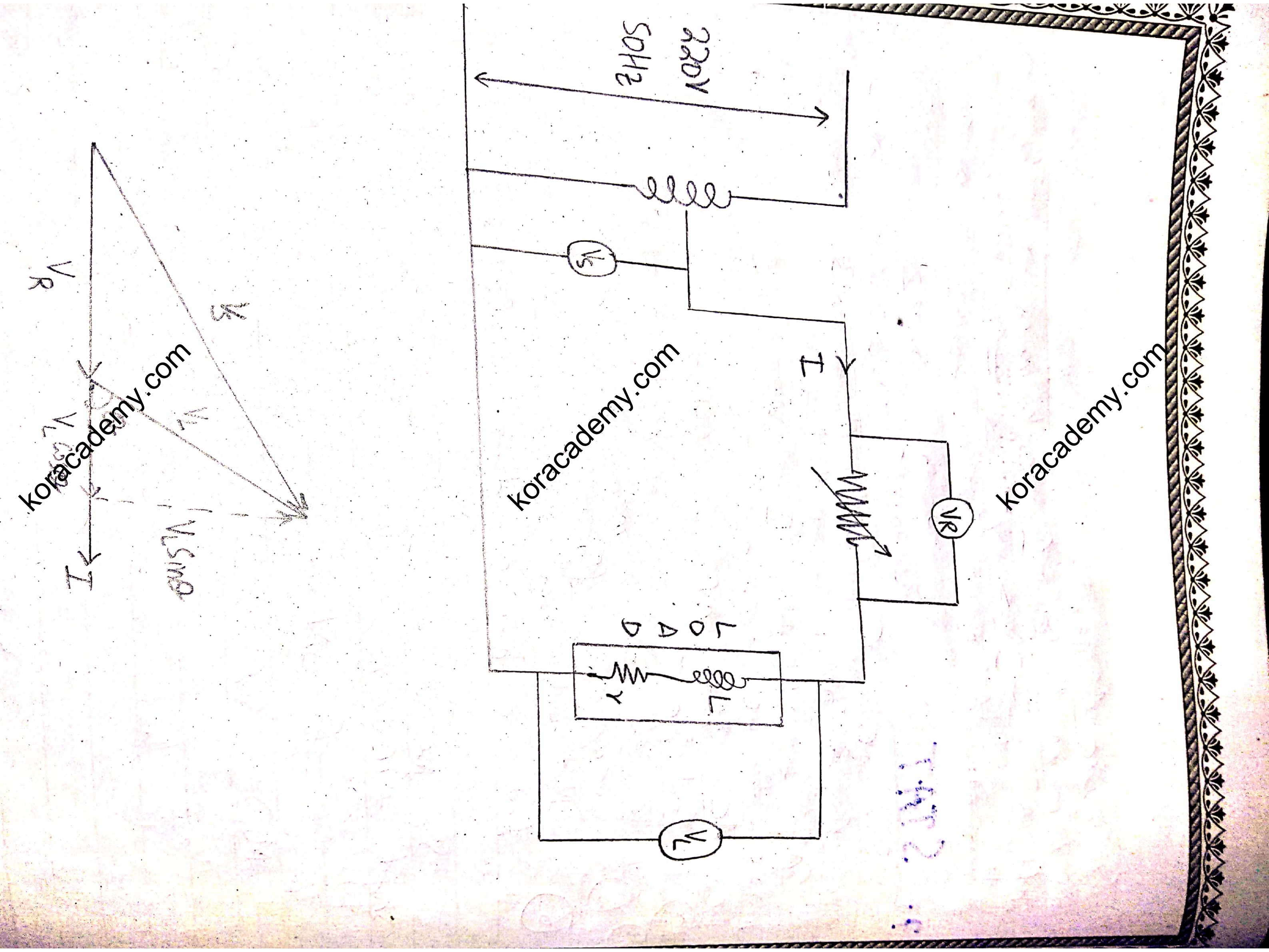
$$P = \frac{V_s^2 - V_L^2 - V_R^2}{2R}$$

Procedure

- The circuit is designed acording to the circuit diagram.
- Observe V_s, V_R and V_L through voltmeters.
- Put these values in the above formula to calculate the power.

Precautions

- The circuit must be properly designed acording to the circuit diagram.
- Observe the readings carefully.
- Calculate the power accurately.



S No	V_S(V)	V_R(V)	V_L(V)	R	P
1	20.9	16.5	9.2	500Ω	0.367
2	30	23.72	5.7		0.162
3	40	32.85	7.74		1.152
4	50.54	40.69	9.39		2.03

Lab 5

29/10/19

To measure single phase power using three ammeters method.

Apparatus

- Auto transformer (power supply)
- Variable resistor (rheostate).
- Inductive load.
- Ammeters.

Theory

Applying KCL at the node.

$$I = I_1 + I_2$$

From phaser diagram

$$I^2 = (I_1 + I_2 \cos\theta)^2 + (I_2 \sin\theta)^2$$

$$I^2 = I_1^2 + I_2^2 \cos^2\theta + 2 I_1 I_2 \cos\theta + I_2^2 \sin^2\theta$$

$$I^2 = I_1^2 + I_2^2 + 2 I_1 I_2 \cos\theta$$

$$\cos\theta = \frac{I^2 - I_1^2 - I_2^2}{2 I_1 I_2}$$ → power factor

As $P = VI\cos\theta$

$V = I_1 R$

$$P = I_1 R I_2 \frac{I^2 - I_1^2 - I_2^2}{2 I_1 I_2}$$

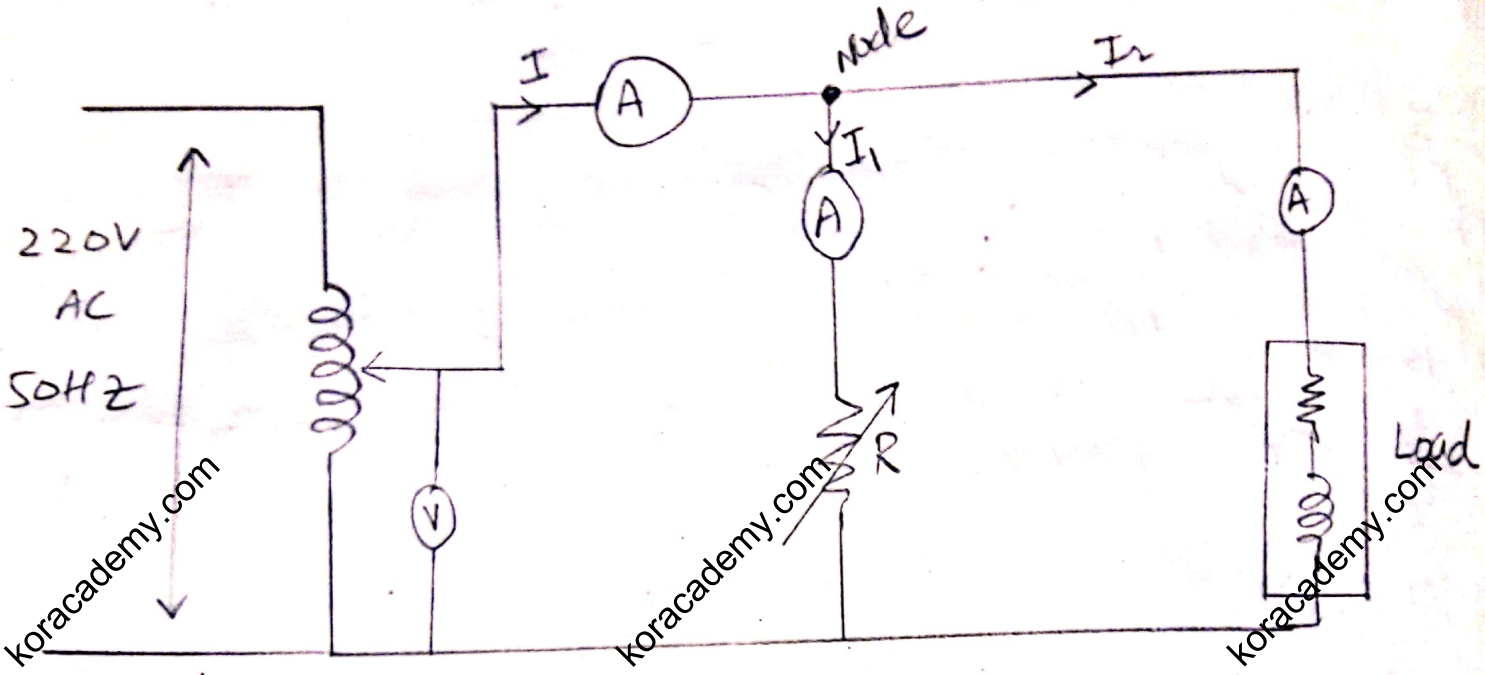
$$P = \frac{R}{2}\left(I^2 - I_1^2 - I_2^2\right)$$

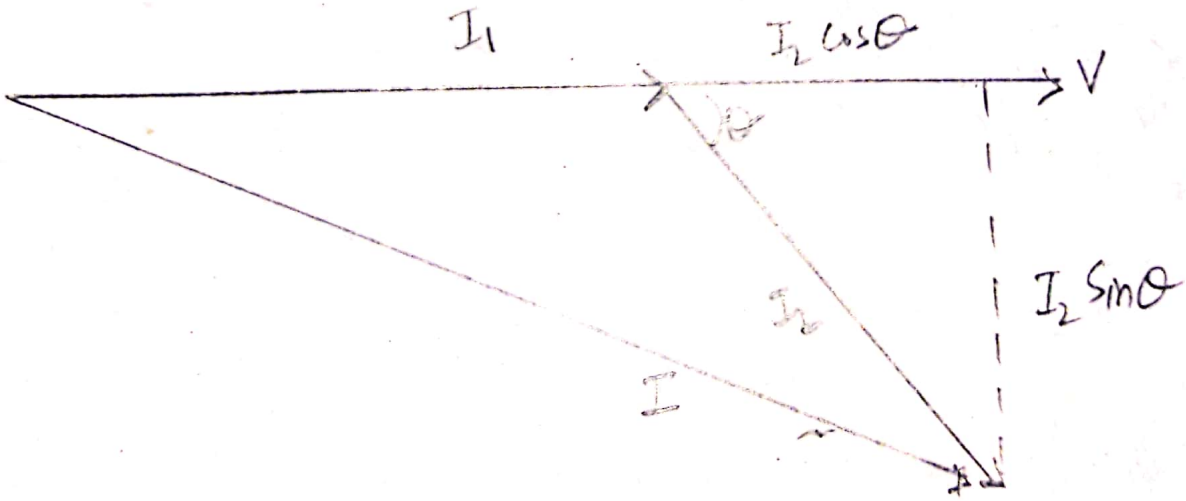
Procedure

- The circuit is designed according to the shown circuit diagram.
- Observe the values of currents I, I_1 and I_2 with the help of ammeters.
- Put these values in the above formula to calculate the power.

Precautions

- The circuit must be properly designed
- Values of circuits should be noted carefully
- Calculations must be accurate





S NO	R	V	$I_{(A)}$	$I_{1(A)}$	$I_{2(A)}$	$\cos\theta$	P
1	100Ω	30V	1.96	0.35	1.6	1.03	58W
2		40V	2.5	0.4	2	1.30	104W
3		50V	3	0.52	2.47	1.031	131.4W

Lab 06

5-11-19

To measure the power factor of a load using wattmeter, voltmeter and ammeter.

Apparatus

Autotransformer.
Ammeter
Wattmeter
Power supply.
Inductive load.

Theory

Autotransformer provides us with the desired voltage or current using a single coil.

The wattmeter is used to measure the average power.

When it is callibrated for DC it works for AC as well. It is because it responds to the average value.

Procedure

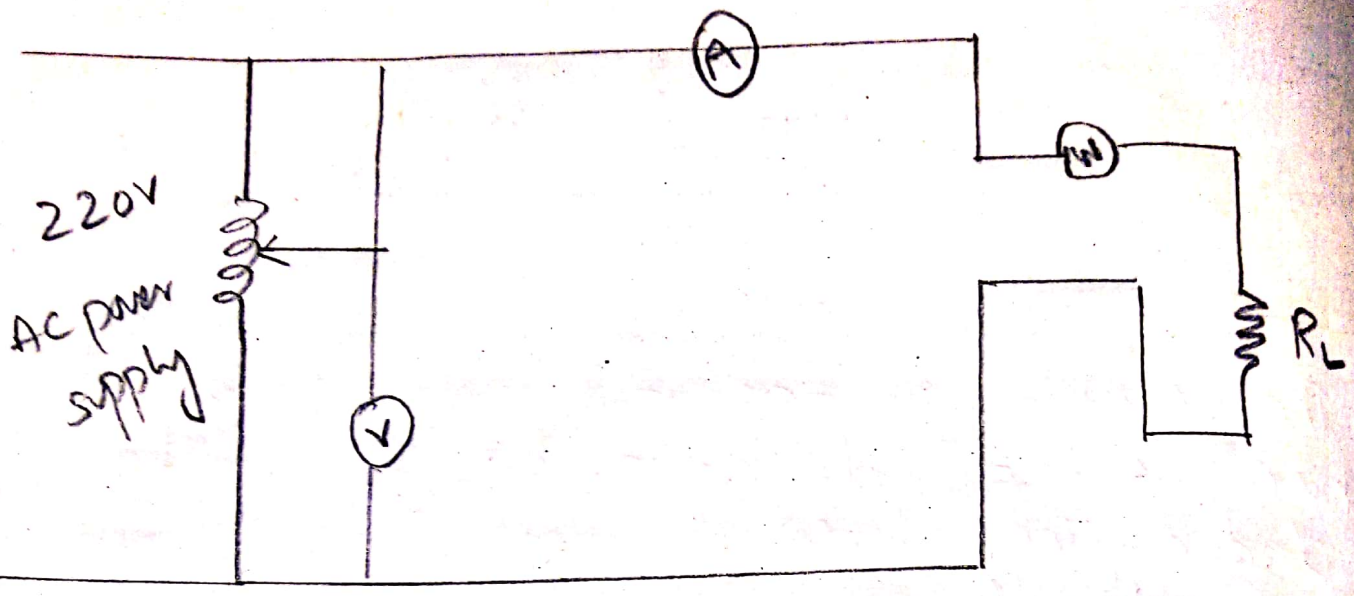
- Make the circuit according to the diagram.
- Turn on the power supply and note down the readings.
- Wattmeter gives the average power across the load.

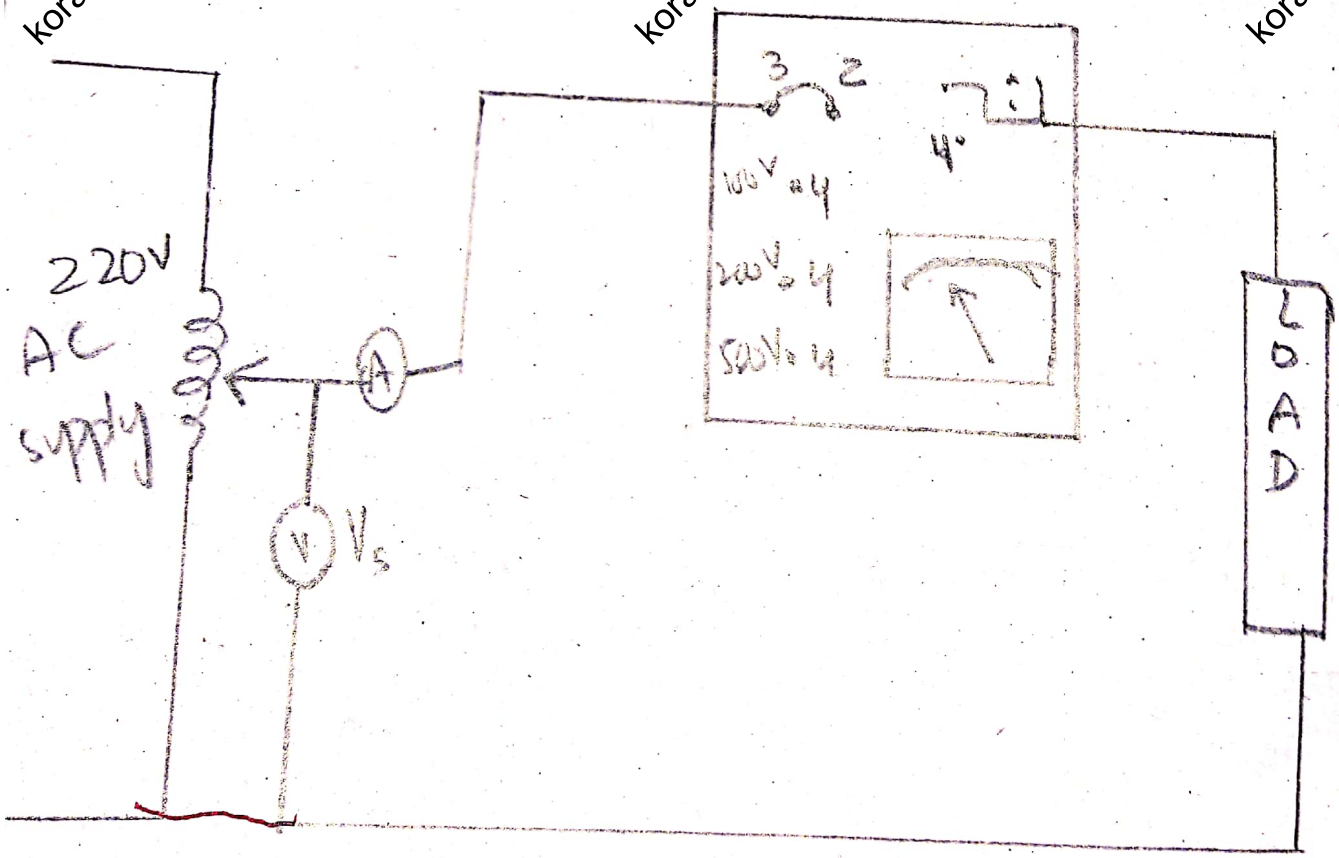
- Voltmeter gives the sauce voltage and ammeter gives current.
- To calculate power factor, use the formula

$$\cos\varphi = \frac{P}{V_{rms} I_{rms}}$$

Precautions

- Make the circuit properly.
- Make connections tightly.
- Take readings several times to avoid the error.





$$P = \frac{1}{T}\int_0^T V_L \, dt$$

$$P.f = \frac{P}{S} = \frac{P}{VI}$$

$$P.f = \cos\varphi = \frac{P}{VI}$$

S No	V(V)	I(A)	P(W)	P.f	avg P.f
1	35	1.2	40	0.952	0.930
2	48	1.5	85	0.902	
3	55	1.8	95	0.959	

1- $P.f = \frac{P}{V_{rms} I_{rms}} = \frac{40}{(30)(1.2)} = 0.952$

2- $P.f = \frac{65}{48 \times 1.5} = 0.902$

3. $Pf = \frac{95}{55 \times 1.8} = 0.952$

Lab 07

26-11-19

To measure current in a circuit using clamp meter.

Theory

Clamp meter is a device used for current measurment. Wire will not break wire in case of clamp meter whereas in case of ammeter we have to break the wire. Clampmeter is mostly used for measuring AC currents. It can also be used for DC but the working principle of both are different.

Working Principle of AC clamp meter

It works on the principle of current transformer. It is used to step down current.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$I_2 < I_1 \Rightarrow N_2 > N_1$$

$$I_1 = \frac{N_2}{N_1} I_2$$

$$\text{If } N_1 = 1 \Rightarrow \boxed{I_1 = N_2 I_2}$$

We know N_2 and ammeter gives the value of I_2. The multiplication of these two values give the desired current.

DC clamp Meter

We cannot use transformer in DC clamp meter

y/c current flowing through the wire is constant. No change in the current flowing through primary coil. So no change in flux and thus the emf induced in the secondary coil is zero.

There is a sensor called Hall effect sensor. It is used to sense magnetic field.

Procedure

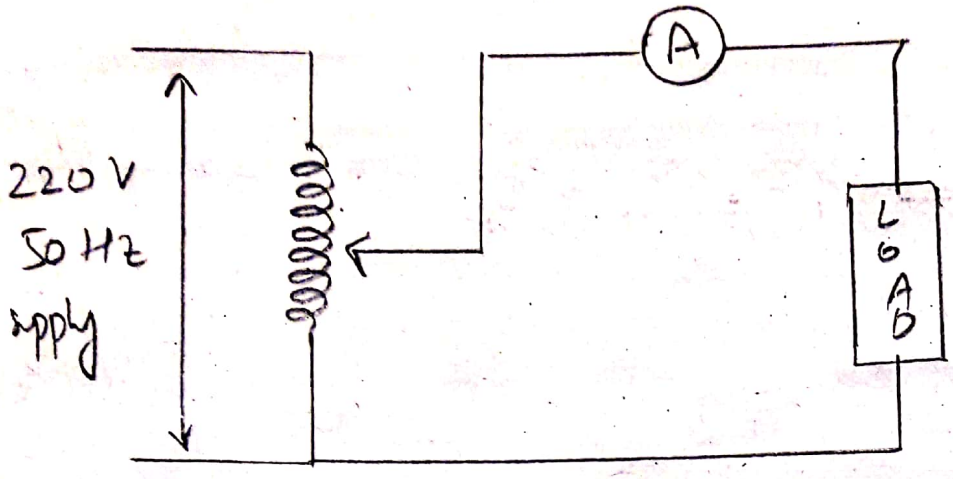
- The circuit is made as shown in the figure.
- Open the jaws of clamp meter and insert the wire through which current is to be measured and close the jaws.
- The reading of clamp meter gives current flowing thrugh the wire.

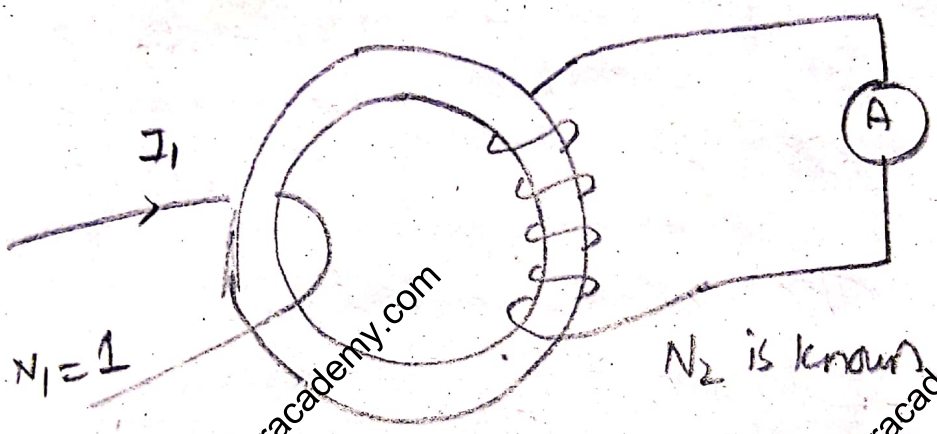
Precautions

- Insert a single wire.
- If we insert two current carrying wires (in opposite direction) the clamp meter will give zero.

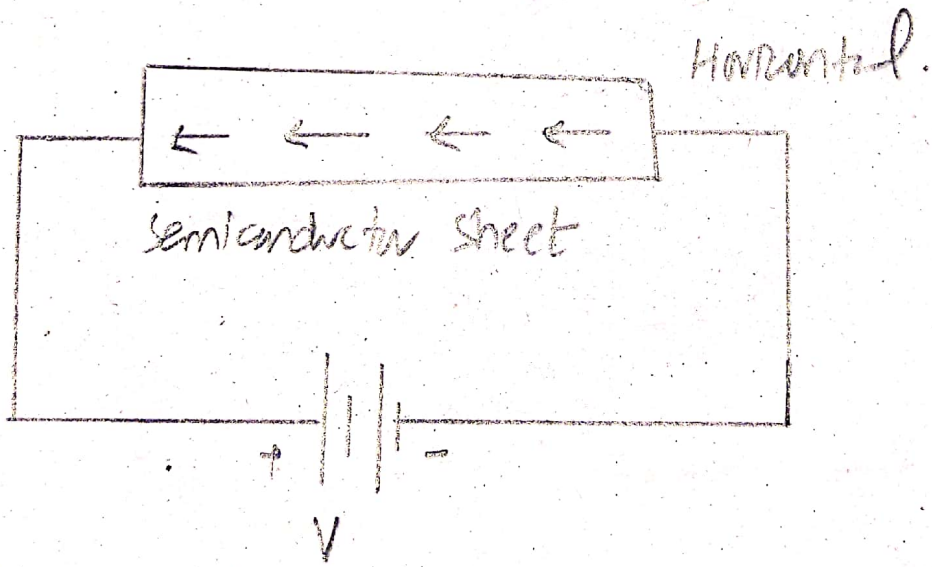
Conclusion

From this experiment we concluded that we can measure current in a wire without physically breaking it with the help of clamp meter.



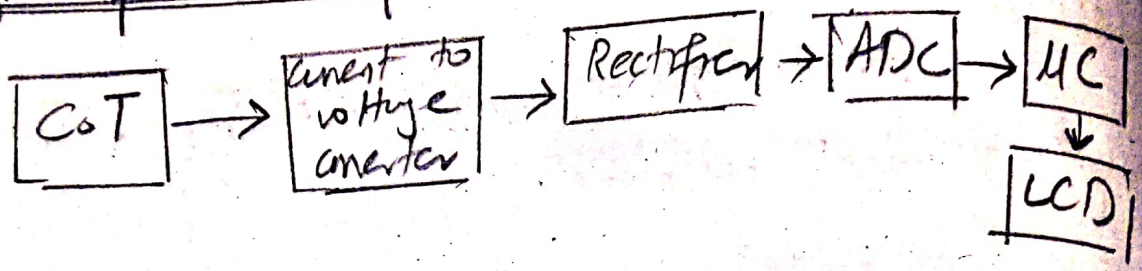


Principle of AC clamp meter

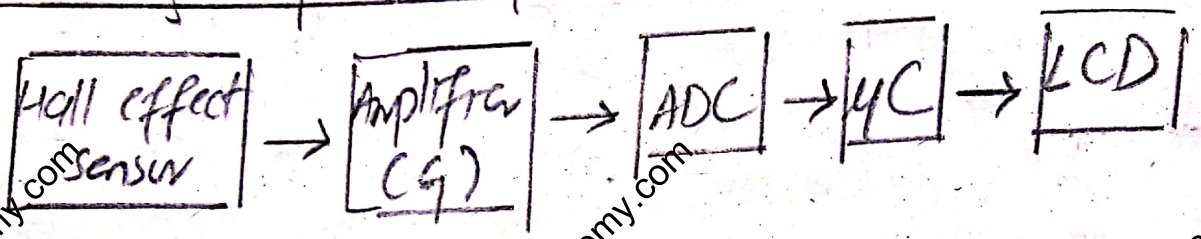


Hall effect Sensor

Block diagram of AC clamp meter

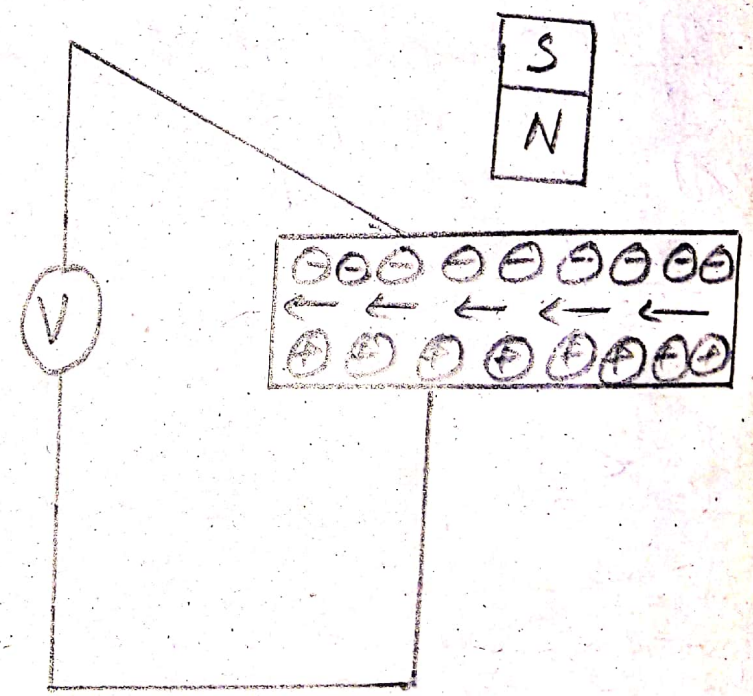


Block diagram of DC clamp meter



Working principle of DC clamp meter

Voltage is proportional to magnetic field (produced by current flowing through the wire)



Lab 08

Missing 18/12/19

03/12/19

To measure the illuminance of light by using lux meter.

Apparatus

Lux Meter

Theory

We will measure the brightness of light using lux meter.

Working Principle

In lux meter we have a photodiode. Photodiode converts light energy into electrical energy. It is always reverse biased. and due to reverse biasing there is always a minute current due to minority charge carriers called Dark current. Dark current is the current in absence of light. when the diode is reverse biased, the depletion region is formed which consists of no free charge carriers and only consists of positive and negative ions ie ions of pentavalent and trivalent impurities.

In depletion region there are electrons in the valence band but they are not free. When light falls on the depletion region, the electrons in the valence band absorb energy ($E = hf$) greater than or equal to forbidden energy gap

jumps to conduction band and are free leaving behind a hole in the valence band. Now depletion region consists of a hole and electron due to which current flows. This current is proportional to the no. of photons (brightness of light) striking the depletion region.

Important Quantities related to light.

i Luminous Flux

The amount of light radiated by a light source in 1 sec. Its unit is Lumen.

ii. Luminous Intensity

It is defined as luminus flux per unit solid angle.

$$1\ cd = \frac{1\ lumen}{st}$$

iii. Illuminance

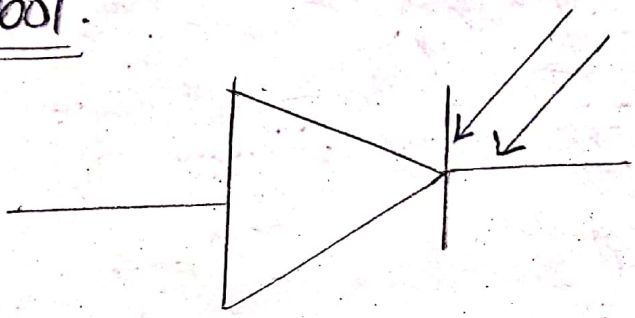
Luminus flux per unit area is called illuminance. Its unit is lux.

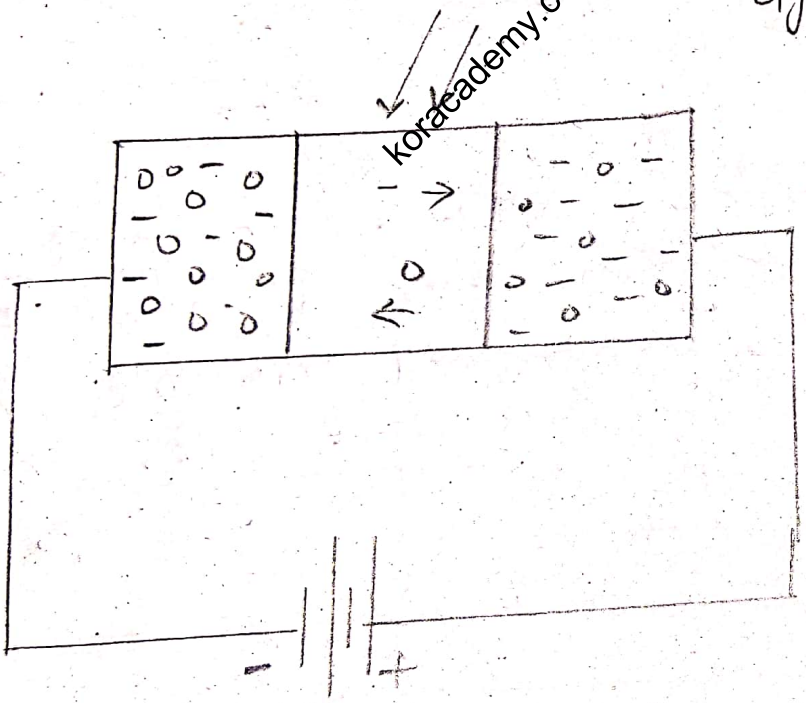
$$1\ lux = \frac{1\ lumen}{m^2}$$

Procedure

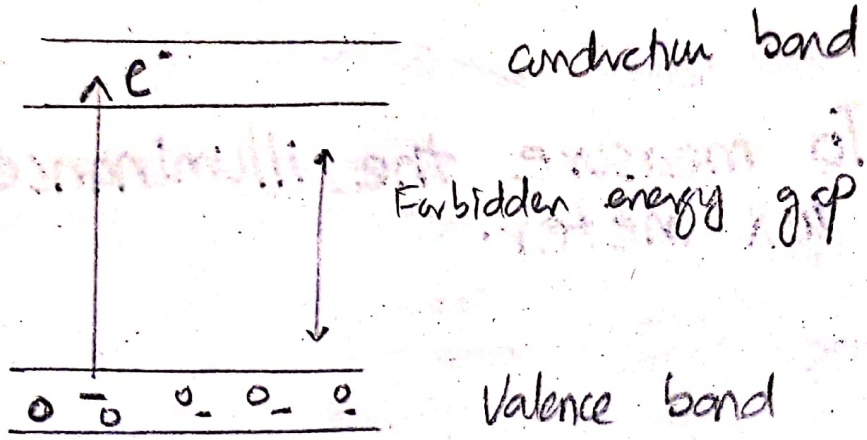
Hold lux meter in front of light source. Meter will indicate illuminance of light.

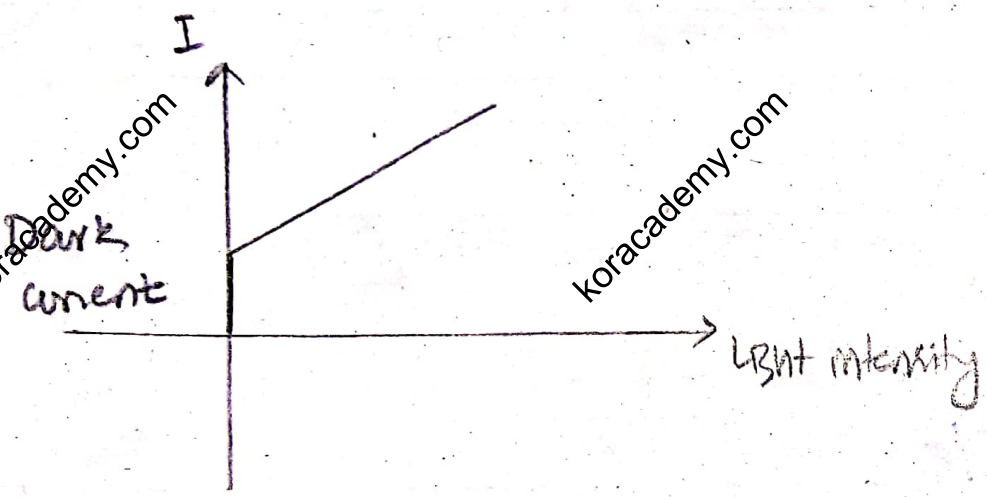
Photodiode symbol.



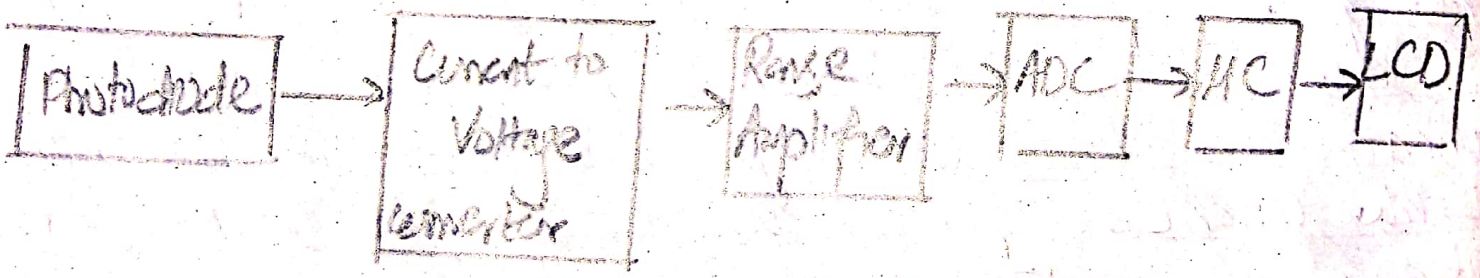


Light falls on depletion region as a result current produces.





Block diagram



Lab 09

To Find the meter constant of a single phase analogue energy meter.

Apparatus

Analogue energy meter.
Load
Supply

Theory

Energy meter is a device that measures the amount of electrical energy consumed by any electrically powered device.

Construction

- It has a voltage coil which is highly inductive.
- Aluminum disc separated by shaft.
- If disc rotates the shaft also rotates.
- To support rotation, it consist of bearings.
- To count rotations, it has registering system.

It has four main parts.

1. **Driving system**
   It consists of voltage coil, current coil and magnetic core and its job is to produce driving torque

ii **Moving system**
   It consists of disc, shaft and bearings.

Due to driving torque, the shaft and disc rotates.

iii. **Breaking System**

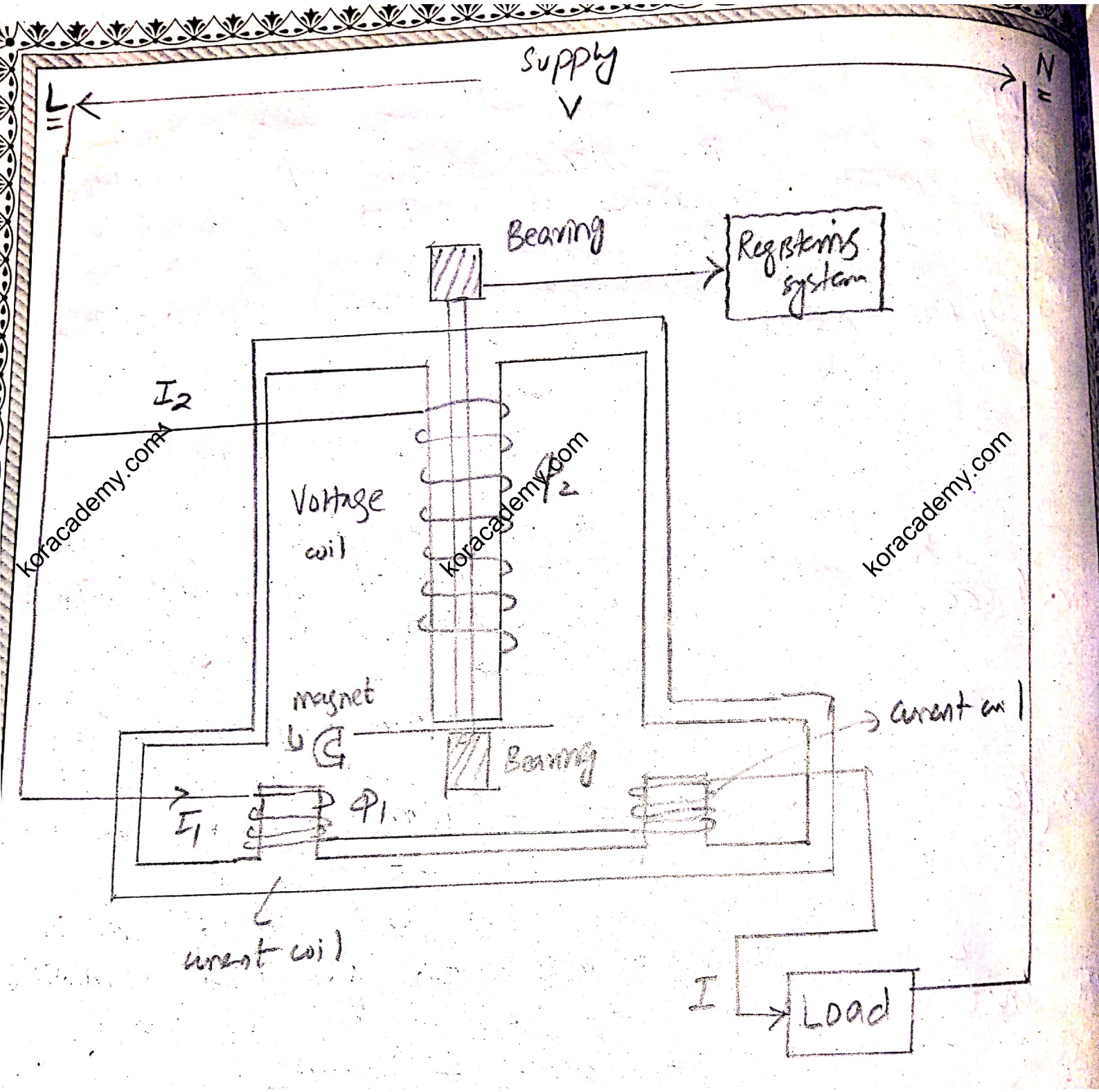
The rotation of disc should be controlled so it consist of U shaped permanent magnet to control the rotation

iv. **Registering System**

Registering system consists of gears that helps to count the revolutions.

Procedure

- Count the no. of revolutions of the disc of energy meter.
- Measure the energy dissipated by the load.
- Put values in formula $K = \frac{N}{E}$ and find the energy constant K.



Observations And Calculations

No. of revolutions $= N = 15$

Energy dissipated $= E = 0.012$ KWh.

$$\text{So } K = \frac{N}{E} = \frac{15}{0.01}$$

$$\Rightarrow K = 1250 \text{ rev/KWh.}$$

Lab 10

To measure unknown resistance using wheatstone bridge

Apparatus

- Wheatstone bridge.
- Supply
- Connecting cables.
- ohm meter.

Theory

Wheatstone bridge is an arrangement that is used to find the resistance of an unknown resistor. It consists of a DC supply and has 4 arms each consisting of a resistor. Two resistors are of known resistances, one resistor is variable and the 4th is unknown. The arms with known resistances are called ratio arms and the arm with variable resistor is called standard arm. The wheatstone bridge is used to find unknown resistance under the balanced condition. ie when the potential difference b/w the two points in which the galvanometer or any other detector is connected becomes zero.

$$R_2 R_3 = R_1 R_4$$

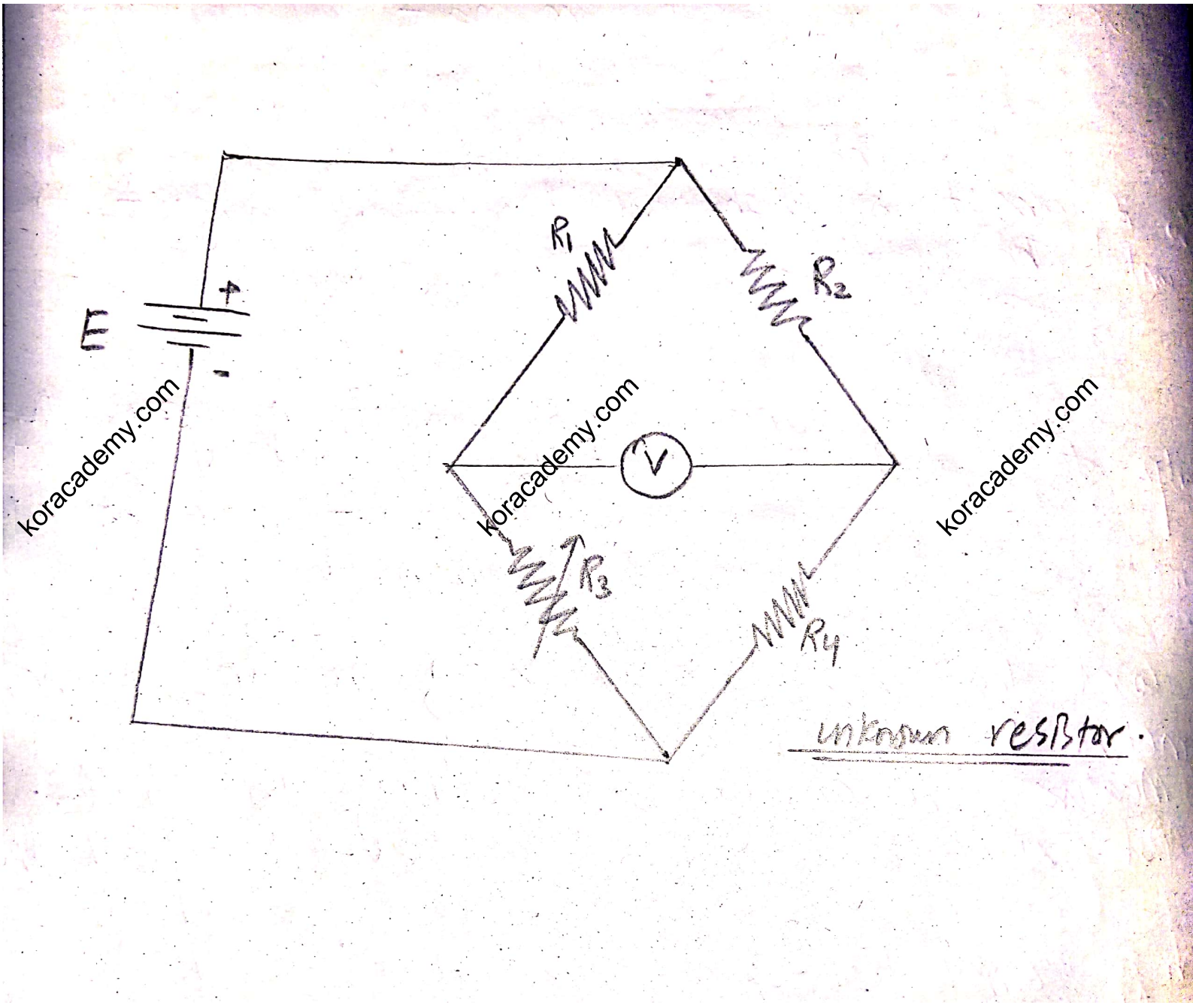
$$\Rightarrow R_4 = \frac{R_2 R_3}{R_1}$$

Procedure

- Supply DC voltage to the wheatstone bridge
- change R_3 ie the variable resistor to make the bridge balanced.
- Using ohmmeter take the true reading of unknown resistor R_4
- Calculate the value of R_4 using the formula

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

- Finally calculate the error.



unknown resistor.

Observations And Calculations

$R_1 = 2.2\,K\Omega$ $R_2 = 4.4\,K\Omega$ $R_3 = 152\,K\Omega$

Tue value of $R_4 = 307\,K\Omega$

Calculated, $R_4 = \frac{R_2 R_3}{R_1}$

$= \frac{4400\,(152 \times 10^3)}{2200}$

$R_4 = 304\,K\Omega$

$\%\ error = \frac{304 - 307}{307} \times 100\,\%$

$= 0.97\,\%$

Lab 11

To measure the insulation resistance using digital insulation meter / tester.

Apparatus

- Digital insulation tester.
- Connecting wires
- Load (electric heater)
- Electric kettle.

Theory

Insulation tester is also called megger. It an instrument which is used to measure the insulation resistance of the electrical machinery system. It consists of a boost converter in which output voltage is greater than the input.

Procedure

To test an electrical equipment that either it is properly insulated or not, follow the following steps!

- Connect one lead of insulation tester to the insulation of equipment and the other to the phase wire.
- If the meter shows a very high reading, the equipment is properly insulated otherwise not.

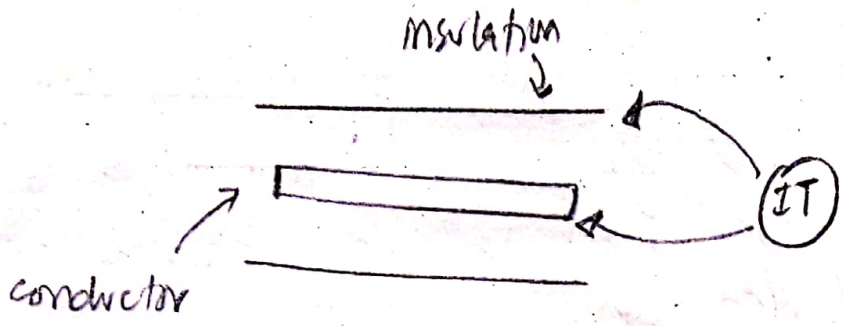
OR

- connect one lead with insulation of electrical instrument and other to neutral wire.

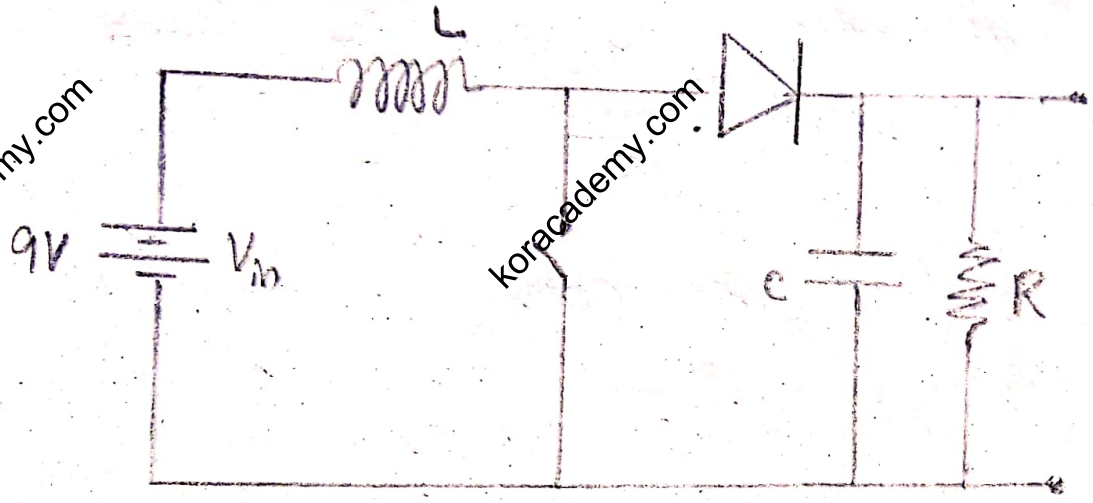
OR

- connect one lead of tester to the insulation of an electrical instrument and the other lead to the earth wire.

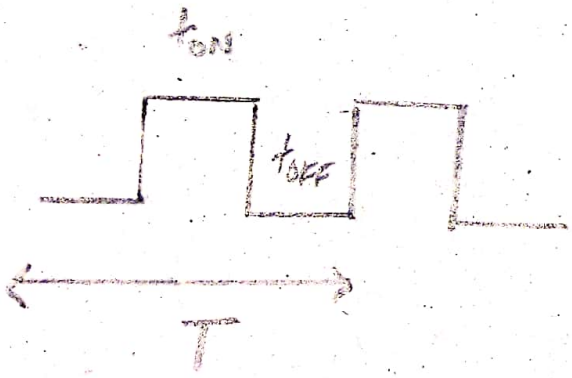
Insulation test for conductor



Boost converter

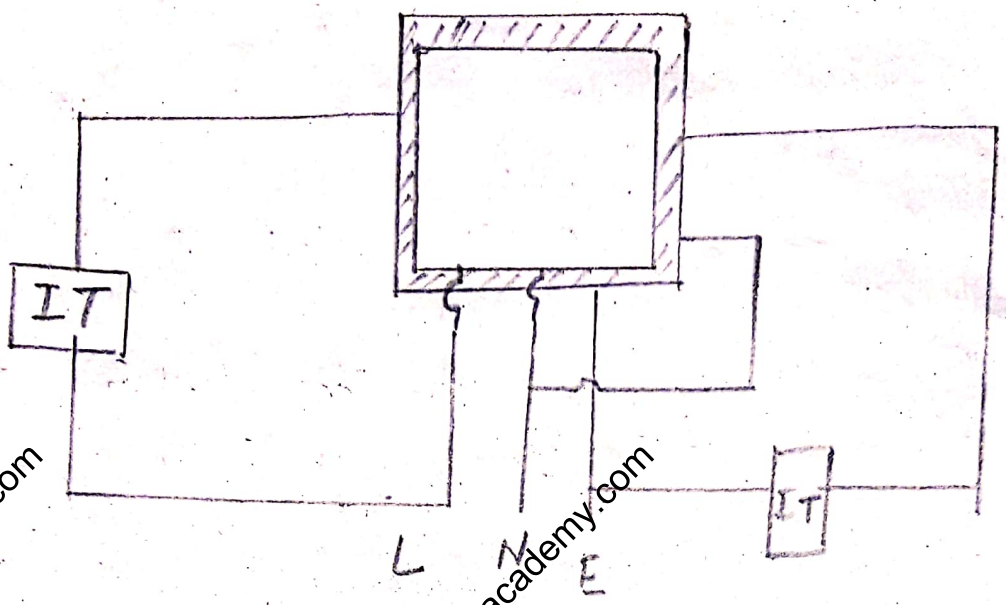


$$V_{out} = \frac{V_{in}}{1-D}$$

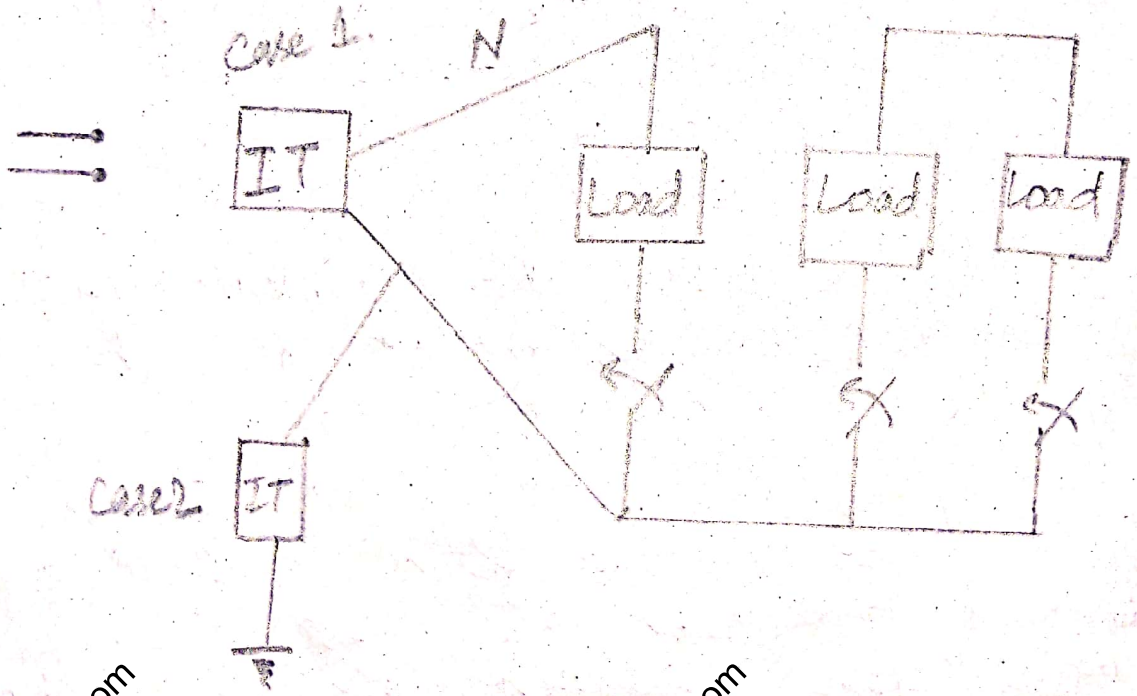


$$D = \frac{t_{ON}}{t_{ON} + t_{OFF}}$$

For electric body Insulation testing.



Insulation Test For Home Wiring.



Lab 12.

To learn the construction and working of DSO

Apparatus. Digital oscilloscope.

Theory Oscilloscope converts electrical signal to a visible trace
It can give us 2 plots.
- Voltage vs time plot.
- Voltage vs voltage plot (Lissajous pattern)

with the help of voltage vs voltage we can find
(i) phase difference.
(ii) Frequency of an unknown signal w.r.t a known signal.

Oscilloscope has two types.
(a) CRO → main part is crt.
(b) DSO

Digital storage Oscilloscope (DSO)

→ It has internal storage, we can use waveform.
→ We can also connect external USB to it.
→ It gives all quantities in numeric form.

Working There are 5 main working parts in DSO.
(i) Vertical system. (ii) Acquisition system
(iii) Digital display system (iv) Triggering system.
(v) Horizontal system.

In coaxial cable, the insulator used b/w two conductors is TEFLON. Outer conductor act as a shield for the signal; signal moves in b/w two conductors in dielectric medium

Probe in probe variable capacitor is present.
→ Oscilloscope has internal square wave generator. we do not get pure square wave so we will change the value of variable capacitor.
X_1 → For single signal X_{10} → attenuating signal 10 times.

(i) **Vertical system** It consists of vertical motion → volt/div → we can control gain → it consist of attenuator and amplifier

(ii) **Acquisition system** It consists of (i) ADC (ii) Memory (iii) Processor.

ADC It converts analogue signal to digital. There are three sub blocks in ADC (a) Sample (b) Quantizer (c) Encoder.

Sample It will take samples of the i/p signal after equal interval of time called the sampling interval and its reverse is called sampling frequency. It converts continuous time signal to discontinuous which is done with the help of a switch.

$$f_s = \frac{1}{T_s} = 500 \text{ M Samples/sec}$$

Quantizer
Analogue discrete time → Digital discrete time.
It will replace all the samples with nearest code of respective level.

Encoder gives bits in o/p.
- converts mid value into binary number.
- when distance b/w levels is same, it is called uniform quantizer.

To decrease quantization error, we don't use uniform

PTO

quantization (without affecting SNR).

Nyquist Criteria According to nyquist criteria To recover original signal from sample $f_s = 2f_m$.

If $f_s < 2f_m$ under sampling

If $f_s > 2f_m$ over sampling

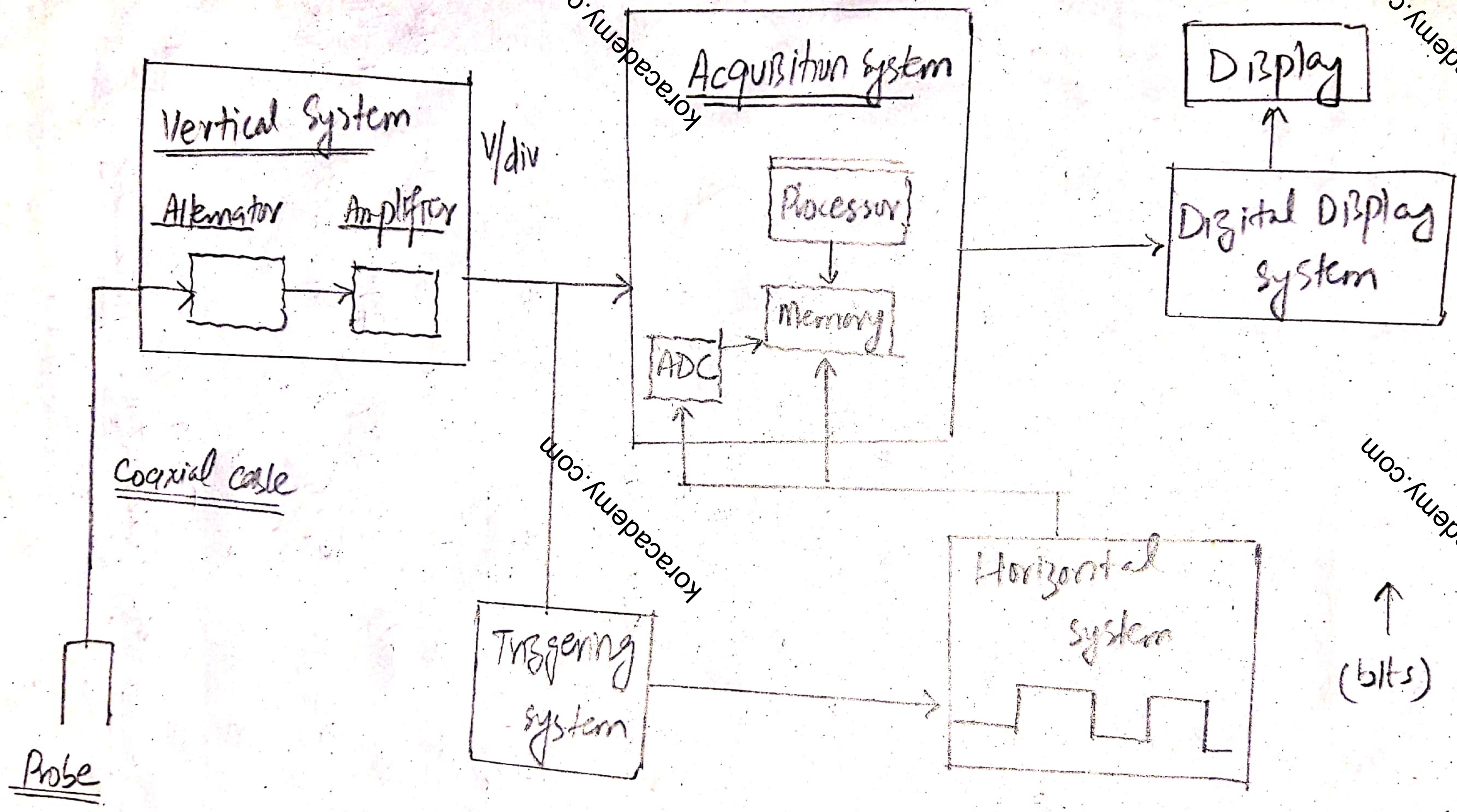
If $f_s = 2f_m$ Nyquist criteria

To watch signal on oscilloscope, sampling frequency must be at least 5 times of f_m of sampling frequency.

Trigger system As it see signal in I/P, it will trigger horizontal system (which consists of clock).

Processor

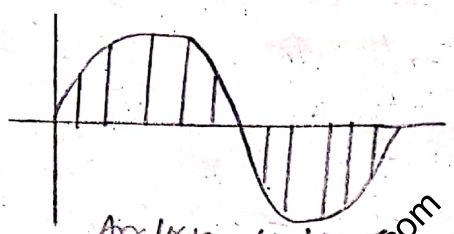
it will calculate the period, frequency, RMS, average values etc.



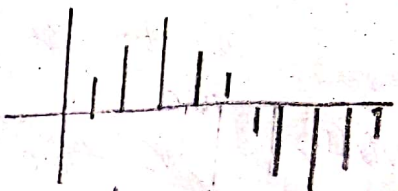
Analog to Digital Converter (ADC)

Analogue signal → Sampler → Quantizer → Encoder → Bits (digital signal)

Sampler:



Analogue continuous time



Analogue discrete time

Quantizer:

→ We introduce error called quantization error.

→ Error can be reduced by using more number of levels.

- Now signal is digital and discrete.

→ It converts analogue to digital.

→ It divide vertical axis into a number of levels.

→ It will assign value to the mid of each level.

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Lab 13

To measure phase difference between two signals using Lissajous.

Apparatus

- Digital storage oscilloscope (DSO).

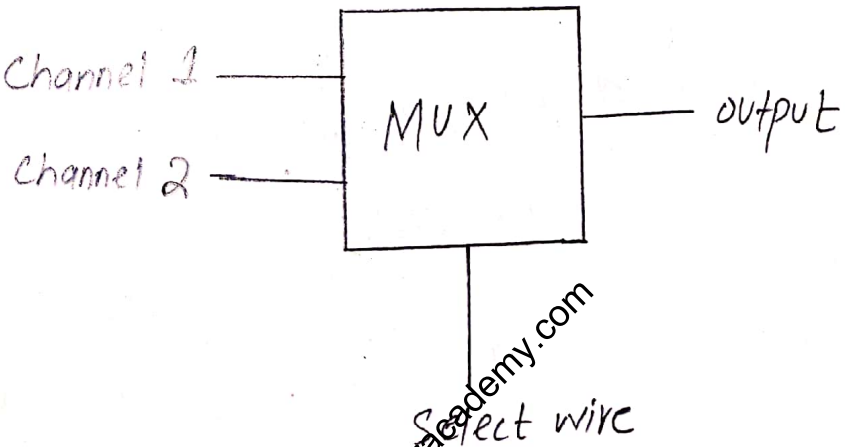
Lissajous Pattern.

2D plot.

Voltage vs Voltage plot

Lissajous pattern is used to find phase difference between two signals.

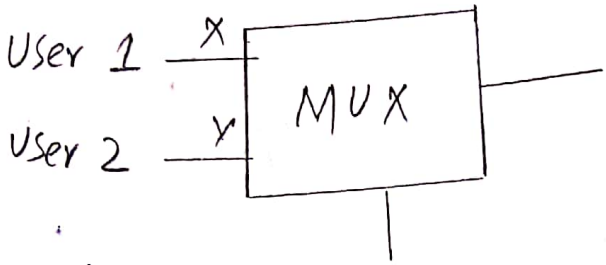
With the help of lissajous pattern, we can find frequency of unknown signal. (Two signals will be applied and lissajous pattern will be given).



Frequency Domain Multiplying

We multiplex two signals in frequency dom
used in 1G mobile technology.

Time Division multiplexing (TDM)



↳ For 1ms user 1 and for other 1ms User 2.

FDM + TDM = 2G Technology

Code Division multiplexing (CDM)

FDM + TDM + CDM = 3G Technology

Orthognal Frequency Division multiplexing

4G Technology

Multiple input multiple output (MIMO)

5G technology.

Why not use multiplexed antenna for more speed

- MUX in ossilloscope is using TDM.

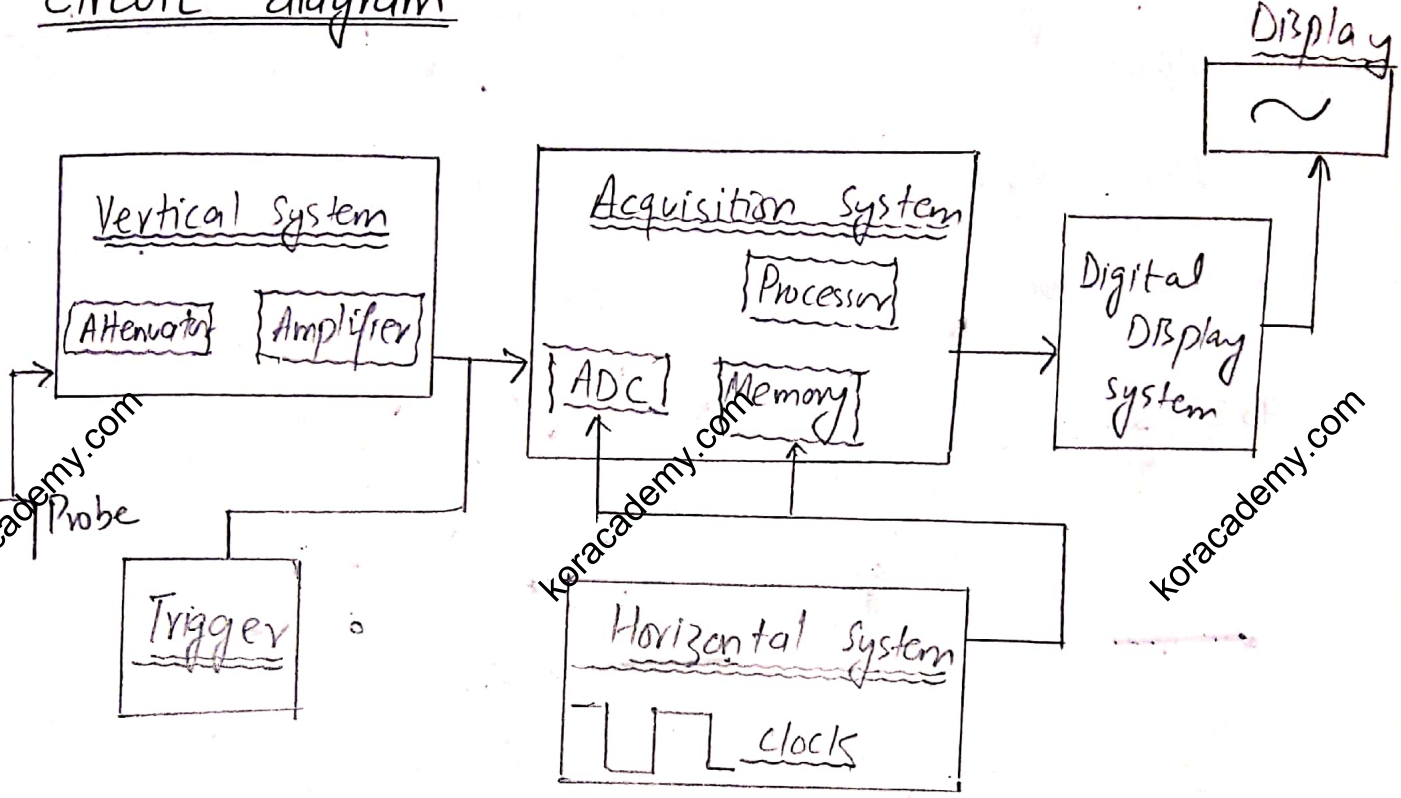
t | x | y

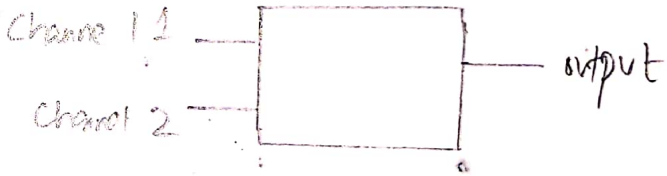
Y vs X Lissajous Pattern

We can set triggering system either to channel 1 or channel 2.

X (channe 1) Y (channel 2)

Circuit diagram



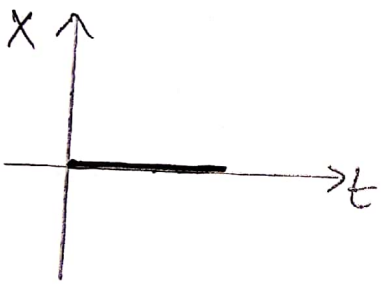


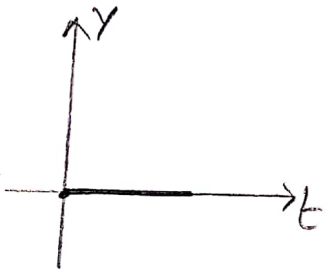
Procedure

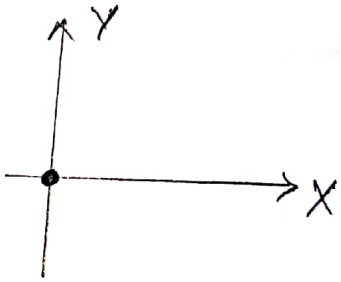
- Circuit diagram should be same here only the addition of multiplexer.
- Multiplexer is because of two channels and we get one output.

- Multiplexer should be in time, frequency phase for both.
- We use two channel which is basically volt vs voltage.
- If $\phi = 0°$, the both waves will be in phase.
- If the angle $\theta = 0° - 90°$ then the circuit will be ellipse.
- If the difference of phase $\phi = 90° - 180°$, then the ellipse will be an opposite side.

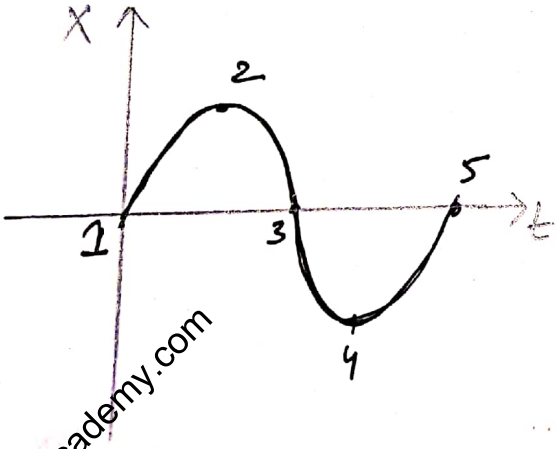
Case 1

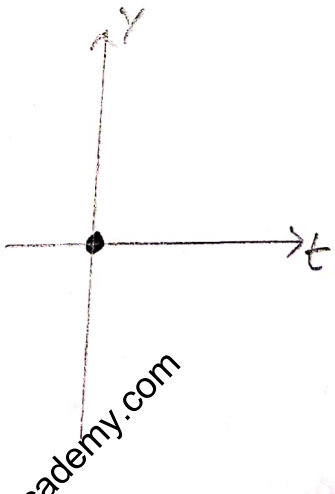


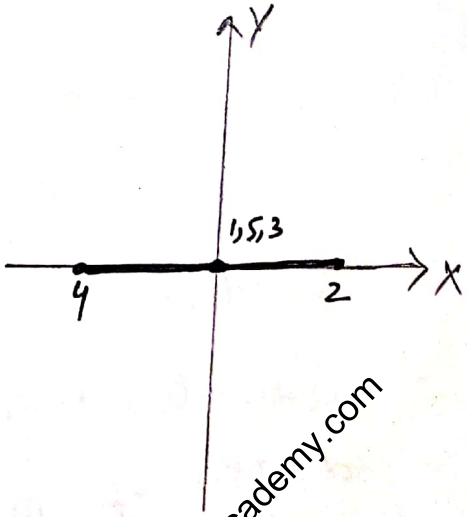




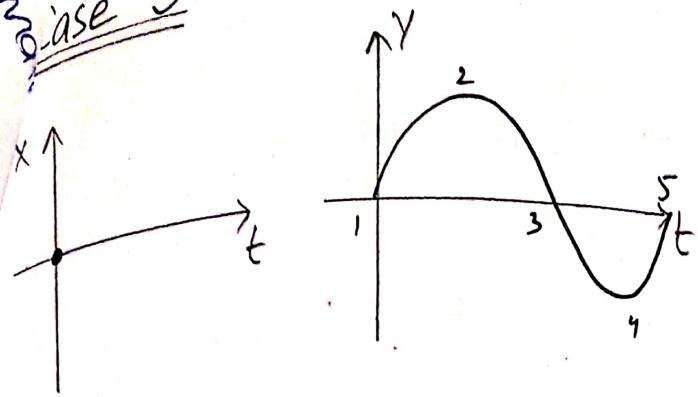
Case 2

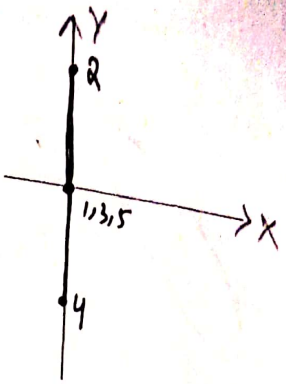




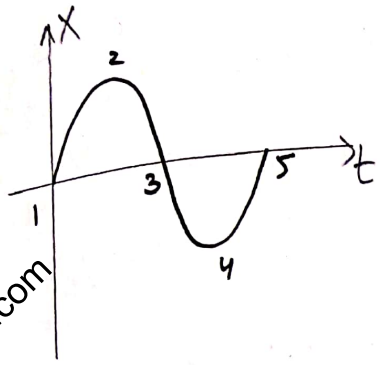


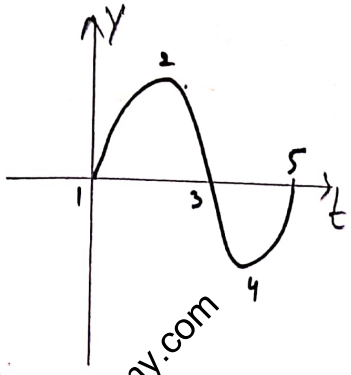
Case 3

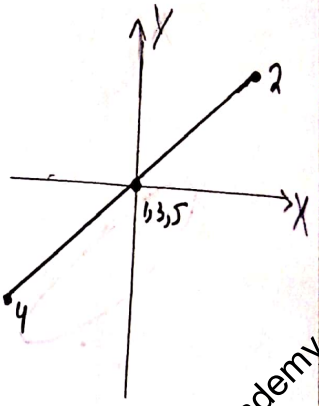




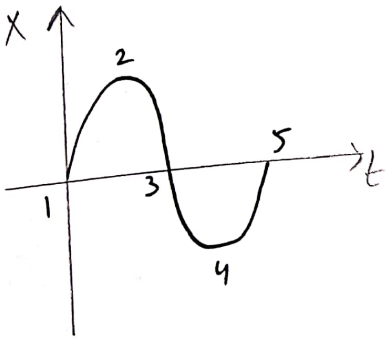
Case 4 $\Delta\phi = 0°$

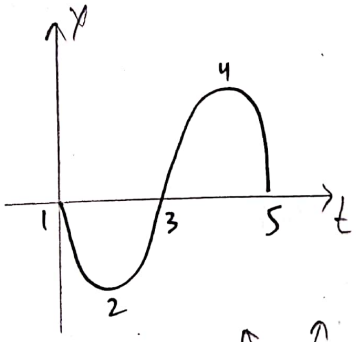


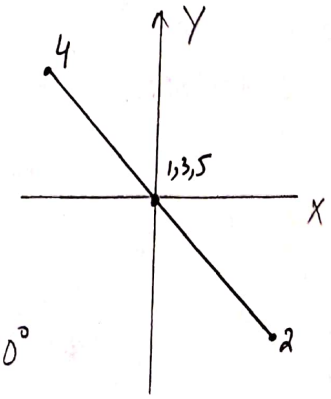


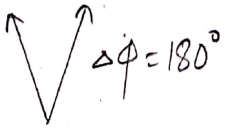


Case 5 $\Delta\phi = 180°$

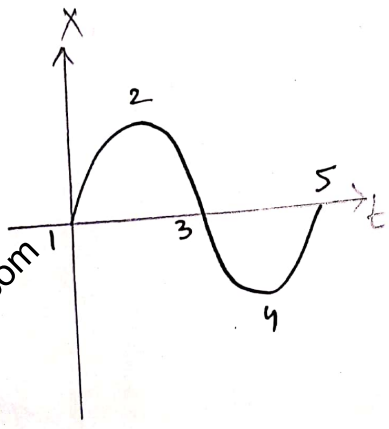


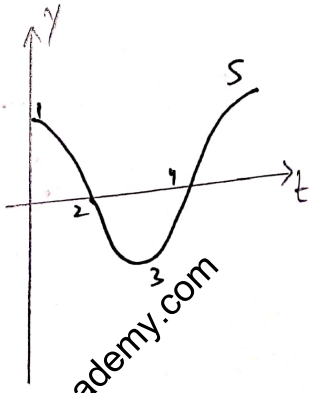


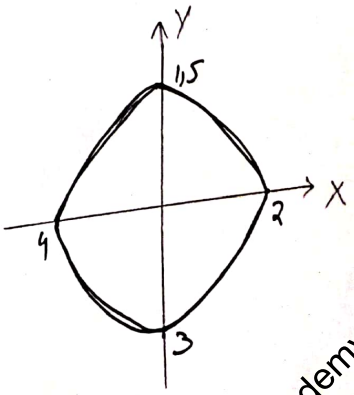




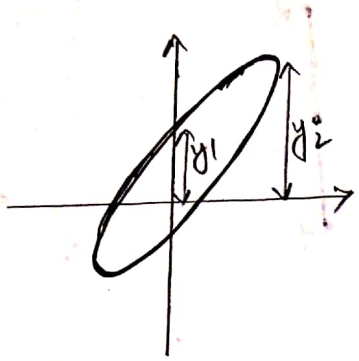
Case 6 $\Delta\phi = 90°$







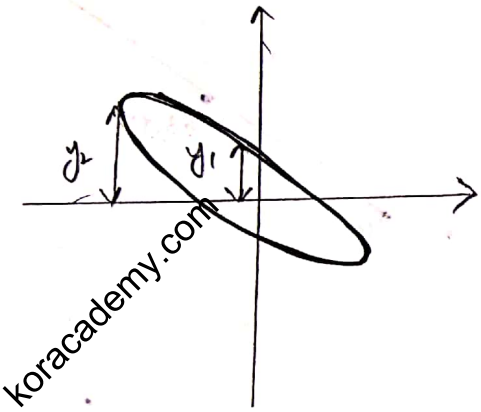
Case 7



→ If the phase difference between two axis is 0 to 90°,

ie $0 \leq \Delta\phi \leq 90°$

$$\Delta\phi = \sin^{-1}\left(\frac{y_2}{y_1}\right)$$



→ If the phase difference between two axis is 90 to 180°,

ie $90° \leq \Delta\phi = 180°$

$$\Delta\phi = 180° - \sin^{-1}\left(\frac{y_1}{y_2}\right)$$

Conclusion.

In this experiment we learned to use the DSO and draw the voltage vs voltage plot on DSO easily and also to find its phase difference.