BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

(21EE101A)

LAB MANUAL

Student Name :

Registration No. :

Department Of
Electrical and Electronics Engineering

Vignan's Foundation for Science, Technology and Research

2021-2022

Vignan's Foundation for Science, Technology and Research

C E R T I F IC AT E

This is to certify that ………………………………………………. bearing Regd. No. …………………………….. is a student of I/IV B.Tech. has completed ………………… experiments in BASICS OF ELECTRICAL AND ELECTRONICS ENGINEERING LAB during the academic 2021-2022.

Signature of
Head of the Department

Signature of Lab
In-charge

VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY & RESEARCH

Vision

To evolve into a Centre of Excellence in Science & Technology through creative and innovative practices in teaching – learning, towards promoting academic achievement and research excellence to produce internationally accepted, competitive and world class professionals who are psychologically strong & emotionally balanced, imbued with social consciousness & ethical values.

Mission

To provide high quality academic programmes, training activities, research facilities and opportunities supported by continuous industry - institute interaction aimed at promoting employability, entrepreneurship, leadership and research aptitude among students and contribute to the economic and technological development of the region, state and nation.

Department of ELECTRICAL AND ELECTRONICS ENGINEERING

Vision

To prepare the students to meet the demands of changing industrial needs and to mould them into successful and ethical professionals, globally accepted in Electrical and Electronics Engineering and allied fields contributing to nation's building.

Mission

M_1: Offering state of art curriculum with innovative practices in teaching learning to pursue career in Electrical and allied fields.

M_2: Providing advanced laboratory facilities and conducive research environment to make them industry ready and equip to carry out higher education.

M_3: Transforming into responsible professionals with leadership qualities, managerial ability, team spirit, social consciousness, human values and ethics.

Program: B.Tech in Electrical and Electronics Engineering

Program Educational Objectives (PEOs)

PEO1: Pursue career in electrical and allied fields in private/ public sector (or) as an entrepreneur.

PEO2: Design, invent and develop novel technology and find creative, innovative solutions to engineering problems through interdisciplinary approach.

PEO3: Apply professional knowledge to solve technical and social problems in economical way by following ethics.

Program Specific Outcomes (PSOs)

PSO1: Design and analyse circuit components, systems that effectively generate, transmit, distribute and utilize electrical power.

PSO2: Apply the appropriate analog, digital techniques and modern engineering software tools in electrical engineering to engage in lifelong learning.

Program Outcomes (POs)

PO1: **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Code of conduct for the laboratory

- All students must observe the Dress code while in the laboratory
- Sandals or open-toed shoes are NOT allowed
- Foods, drinks and smoking are NOT allowed
- All bags most be left at the indicated place
- The lab timetable must be strictly followed
- Be PUNCTUAL for your laboratory session
- Experiment must be completed within the given time
- Noise must be kept to a minimum
- Workspace must be kept clean and tidy at all time
- Handle all apparatus with care
- All students are liable for any damage to equipment due to their own negligence
- All equipment, apparatus, tools and components must be RETURNED to their original place after use
- Students are strictly PROHIBITED from taking out any items from the laboratory
- Students are NOT allowed to work alone in the laboratory without the lab supervisor
- Report immediately to the lab supervisor if any injury occurred
- Report immediately to the lab supervisor if any damages to equipment

BEFORE LEAVING LAB:

- Place the stools under the lab bench
- Turn off the power to all instruments
- Turn off the main power switch to the lab bench
- Please check the laboratory notice board regularly for updates

Lab In-charge

BEEE laboratory list of experiments

S.No	Name of the Experiment
1	Verification of Ohm’s Law
2	Verification of KCL
3	Verification of KVL
4	Measurement of Power
5	Measurement of Energy
6	Transformation Ratio of a Single Phase Transformer
7	P-N Junction Diode Characteristics
8	Zener Diode Characteristics
9	Determination of R.M.S Values of Various Waveforms
10	Determination of Impedance in Complex AC Circuits

INDEX

S.No	Experiment	Page.No	Marks	Signature
1				
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6				
7				
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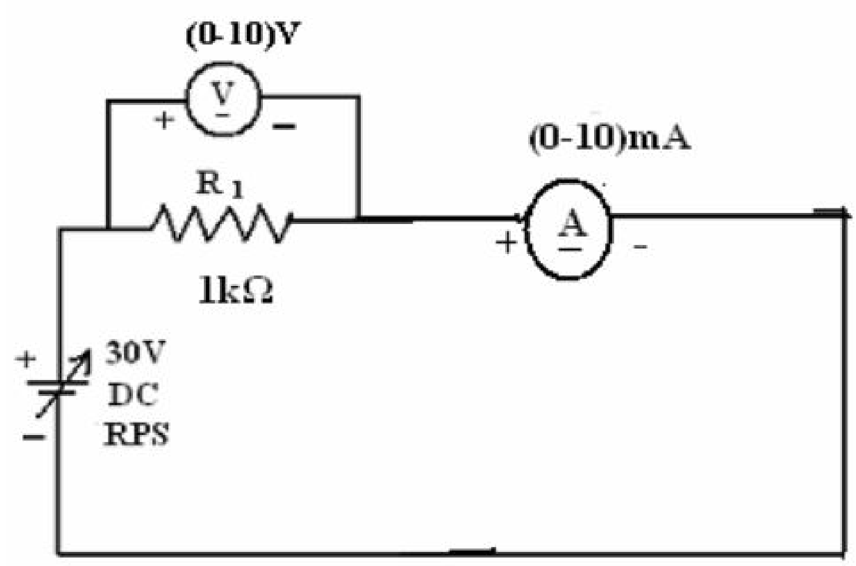
9				
10				

1. OHM'S LAW

Circuit Diagram:



VERIFICATION OF OHM'S LAW

EXP. NO:
DATE:

Aim: To conduct a suitable experiment for verifying ohm's law theoretically and practically.

Apparatus:

S.No	Apparatus	Range/Value	Type	Quantity
1	Dual R.P.S	(0-30 V)	DC	1
2	Ammeter	(0-10mA)	DC	1
3	Voltmeter	(0-10V)	DC	1
4	Bread Board	--	--	1
5	Resistor			1
6	Connecting wires		Single strand	As required

Procedure:

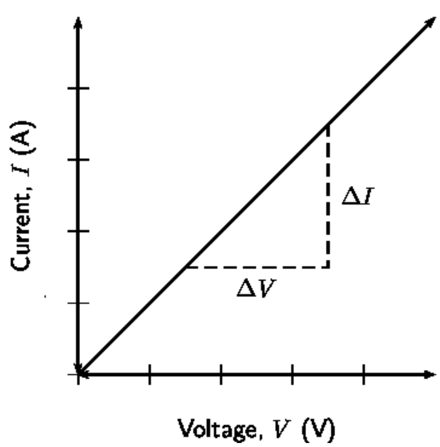
1. Connections are made as per the circuit diagram and switch on the power supply.
2. Vary the supply voltage (V) in steps and measure the corresponding value of current (I).
3. Switch off the power supply.
4. Plot the graph between voltage and current.
5. Calculate the value of resistance from the graph.
6. Measure the value of resistance(R) using multimeter.
7. Compare the values of R obtained by different methods.

Observations:

1. **Value of Resistance (obsereved in multimeter) =**
2. **Value of Resistance calculated from experiment:**

S.No.	Voltage (Volts) **V**	Current (mA) **I**	Resistance (KΩ) $\mathbf{R = \frac{V}{I}}$

Model Graph:



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Theoretical Calculations:

Resistance calculation using Colour Coding:

Value of Resistance calculated from Graphical Method:

Slope $= \frac{\Delta I}{\Delta V} =$

Resistance, R $= \frac{1}{\text{Slope}} = \frac{\Delta V}{\Delta I} =$

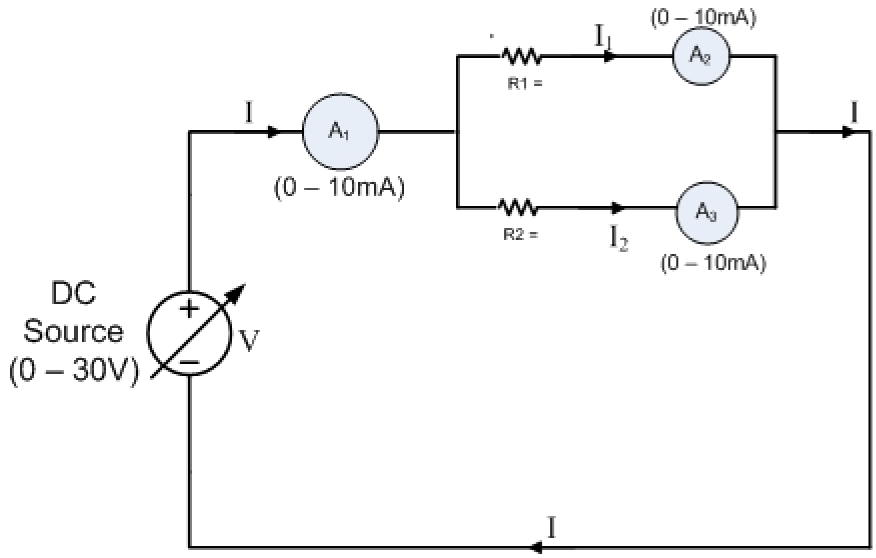
Result:

Comparison Table:

S.No.	R value obtained from Colour coding	R value measured by multimeter	R value obtained practically from graph

2. Kirchoff's Current Law (KCL)

Circuit Diagram:



VERIFICATION OF KCL

EXP. NO:
DATE:

Aim: Verify KCL theoretically and practically.

Apparatus:

S.No	Apparatus	Range	Type	Quantity
1	Dual R.P.S	(0-30 V)	DC	1
2	Ammeter	(0-10mA)	DC	3
3	Bread Board	-	-	1
4	Resistors	R_1 = R_2 =		
5	Connecting wires		Single strand	As required

Procedure:

1. Make the connection according to the circuit diagram
2. Switch on the power supply
3. Vary the voltage in steps and measure the corresponding values of current in the three ammeters
4. Switch off the power supply.
5. Verify that for each value of applied voltage $I = I_1 + I_2$
6. Compare the values obtained practically with the theoretical values.

Observation table:

Practical Values:

S.No	Applied Voltage (Volts)	I (mA) (from A_1)	I_1 (mA) (from A_2)	I_2 (mA) (from A_3)	$I_1 + I_2$ (mA)
1	5				
2	10				
3	15				
4	20				
5	25				

Theoretical Values:

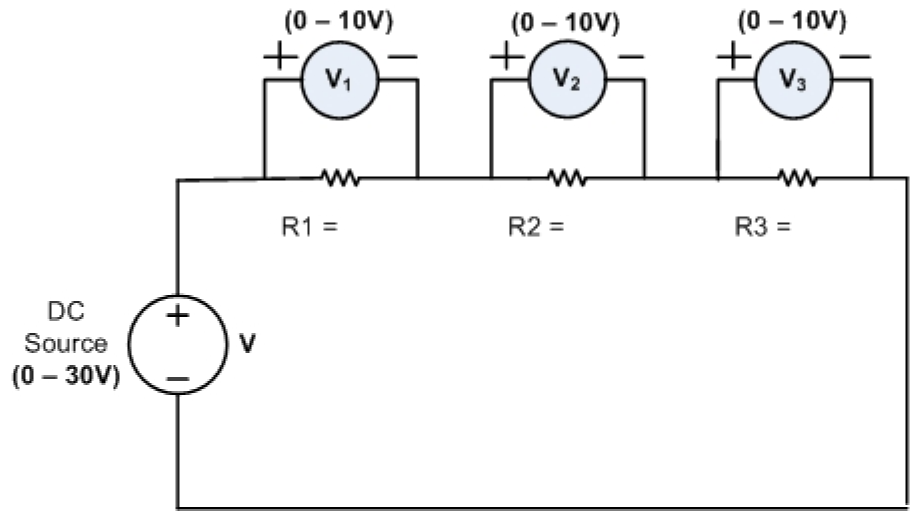
S.No	Applied Voltage (Volts)	I (mA)	I_1 (mA)	I_2 (mA)	$I_1 + I_2$ (mA)
1	5				
2	10				
3	15				
4	20				
5	25				

Theoretical Caluculations:

Result:

3. Kirchoff's Voltage Law (KVL)

Circuit Diagram:



VERIFICATION OF KVL

EXP. NO:
DATE:

Aim: Verify KVL theoretically and practically.

Apparatus:

S.No	Apparatus	Range	Type	Quantity
1	Dual R.P.S	(0-30 V)	DC	1
2	Voltmeter	(0-10V)	DC	3
3	Bread Board	-	-	1
4	Resistors	R1 = R2 = R3 =		
5	Connecting wires		Single strand	As required

Procedure:

1. Make the connection according to the circuit diagram
2. Switch on the power supply
3. Vary the supply voltage in steps and measure the corresponding values of voltage in the three voltmeters.
4. Switch off the power supply.
5. Verify that for each value of applied voltage $V = V_1 + V_2 + V_3$
6. Compare the values obtained practically with the theoretical values.

Observation table:

Practical Values:

S.No.	Applied Voltage(V)	V_1 (V)	V_2 (V)	V_3 (V)	$V = V_1 + V_2 + V_3$ (V)
1	5				
2	10				
3	15				
4	20				
5	25				
6	30				

Theoretical Values:

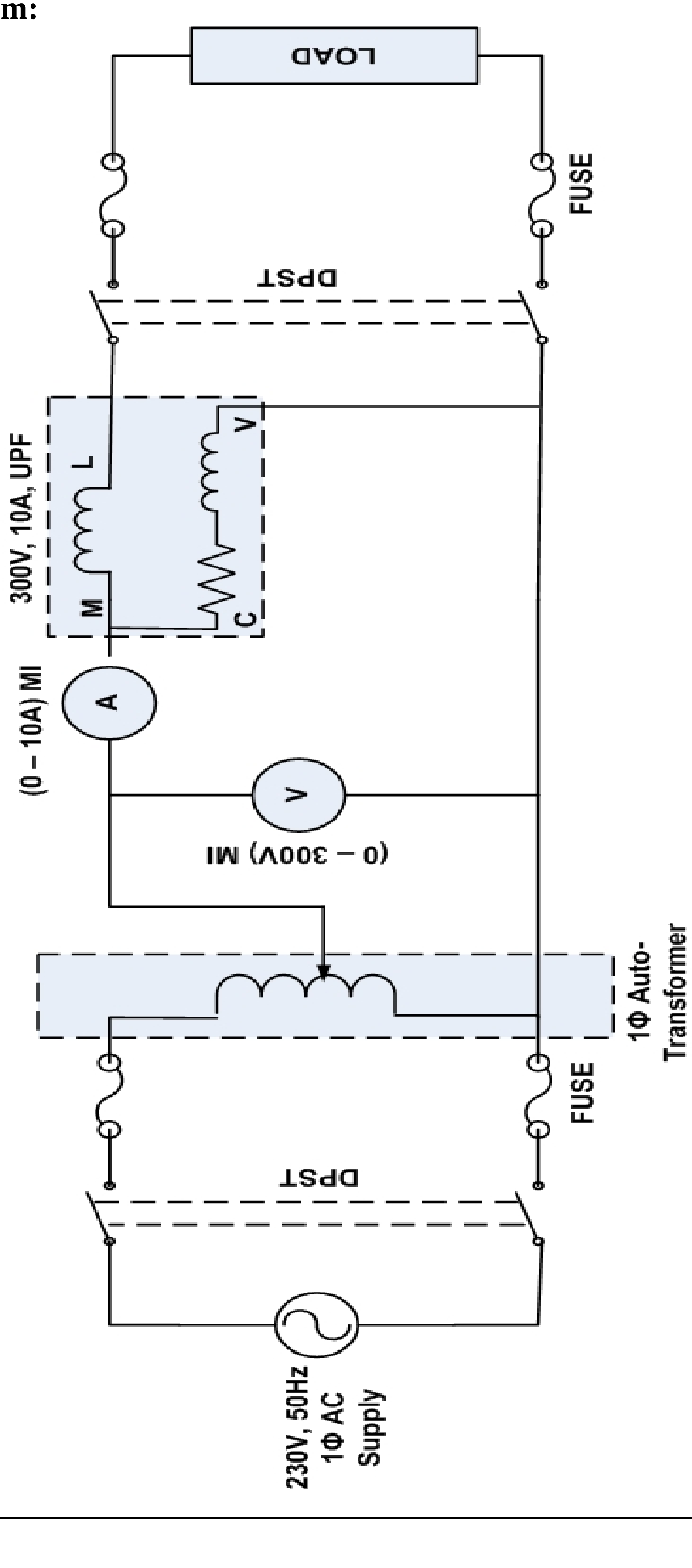
S.No.	Applied Voltage(V)	V_1 (V)	V_2 (V)	V_3 (V)	$V = V_1 + V_2 + V_3$ (V)
1	5				
2	10				
3	15				
4	20				
5	25				
6	30				

Theoretical Caluculations:

Result:

4. Measurement of Power

Circuit diagram:



MEASUREMENT OF POWER

EXP. NO:
DATE:

Aim: - To measure Electrical Power in a Single Phase AC Circuit using wattmeter.

Apparatus:

Sl.No	Apparatus	Range	Type	Quantity
1.	Watt meter	300 V, 10 A, UPF	Electro dynamo meter	1
2.	Voltmeter	(0 - 300 V)	MI	1
3.	Ammeter	(0 - 10 A)	MI	1
4.	Resistive Load	13KW, 13 A	Resistive	1
5.	Auto Transformer	230V/(0-270V), 10A, 50Hz	Single phase	1

Procedure:

1. Connect the circuit as per the circuit diagram
2. Switch on the power supply
3. Apply the rated voltage of 230V by slowly adjusting the auto transformer.
4. Switch on the load & vary the load in steps.
5. Note down the readings of all the meters for each step.
6. Repeat the procedure until 10A of load current is reached.
7. Remove the load in steps.
8. Switch of the load.
9. Reduce the voltage to zero by varying the auto transformer.
10. Switch off the power supply

Observations:

Practical values:

Sl. No	Applied Voltage V (Volts)	Current in amps I_L (Amps)	Power P (Watts)
1			
2			
3			
4			
5			

Theoretical values:

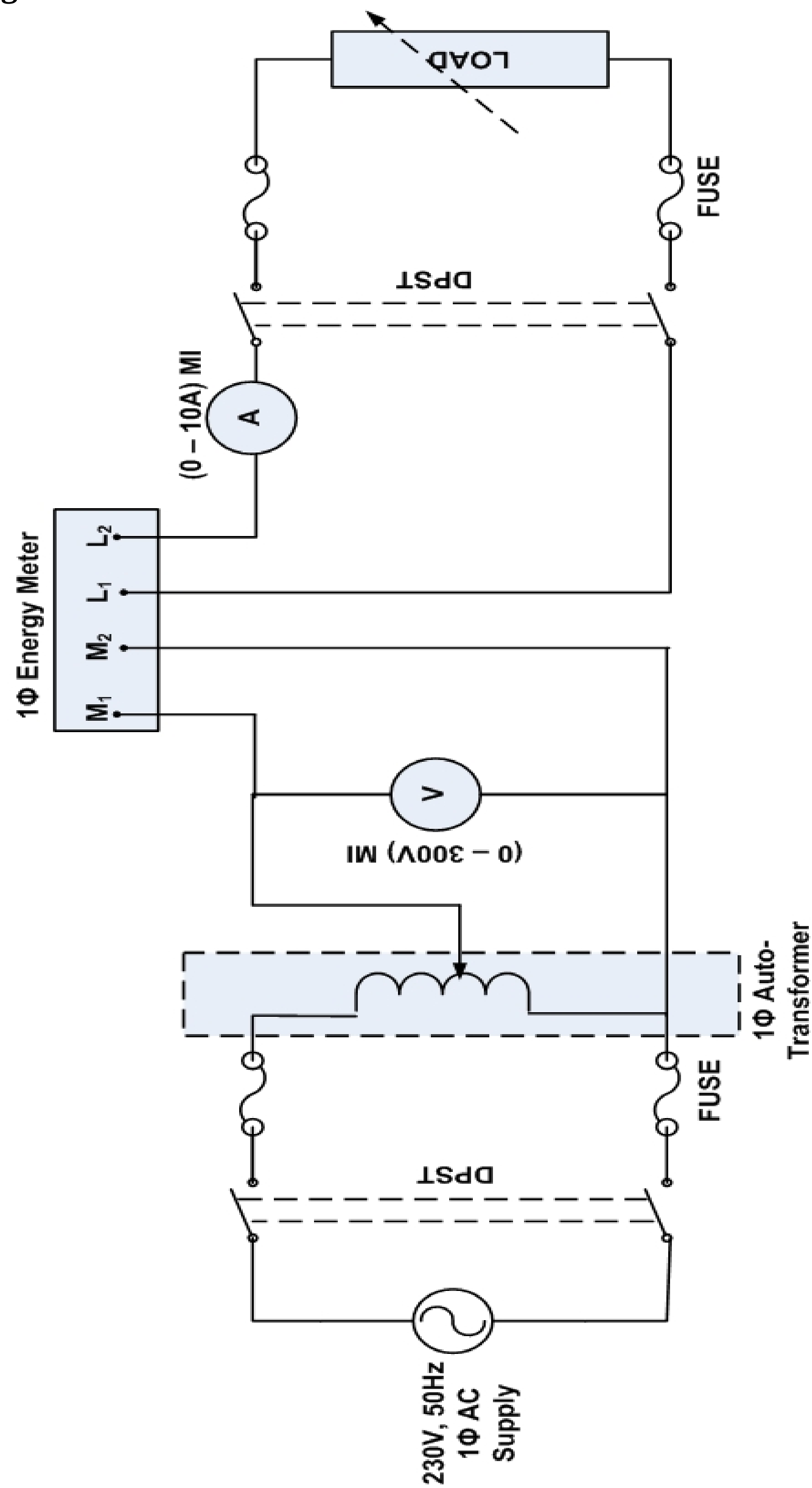
Sl. No	Applied Voltage V (Volts)	Current in amps I_L (Amps)	Power P (Watts)
1			
2			
3			
4			
5			

Theoretical Caluculations:

Result:

5. Measurement of Energy

Circuit diagram:



MEASUREMENT OF ENERGY

EXP. NO:
DATE:

Aim: - Measurement of Electrical Energy Single Phase AC Circuit by using energy meter.

Apparatus:

Sl.No	Apparatus	Range	Type	Quantity
1	Energy meter	240V,15A, K=1600 Revoluations/kWh	Electro dynamo meter	1
2	Voltmeter	(0 - 300 V)	MI	1
3	Ammeter	(0 - 10 A)	MI	1
4	Resistive Load	13KW, 13 A	Resistive	1
5	Auto Transformer	230V/(0-270V),10A, 50Hz	Single phase	1
6	Stop watch	-	Digital	1

Procedure:

1. Connect the circuit as per the circuit diagram
2. Switch on the power supply
3. Apply the rated voltage of 230V by slowly adjusting the auto transformer.
4. Switch on the load & vary the load in steps.
5. Determine the number of revelations completed by the aluminium disc for the given time at each step of load variation
6. Repeat the procedure until 10A of load current is reached.
7. Remove the load in steps.
8. Switch of the load.
9. Reduce the voltage to zero by varying the auto transformer.
10. Switch off the power supply

Observations:

Meter constant K = _________ rev/KWh

Practical Values: $E = \frac{N}{K} \times 1000\,\text{Wh}$

Sl. No	Applied Voltage V (Volts)	Current in amps I_L (Amps)	Time (Sec)	N (No. of revolutions)	Electric Energy (Wh)
1					
2					
3					
4					
5					

Theoretical Values: E = V*I*t (Wh)

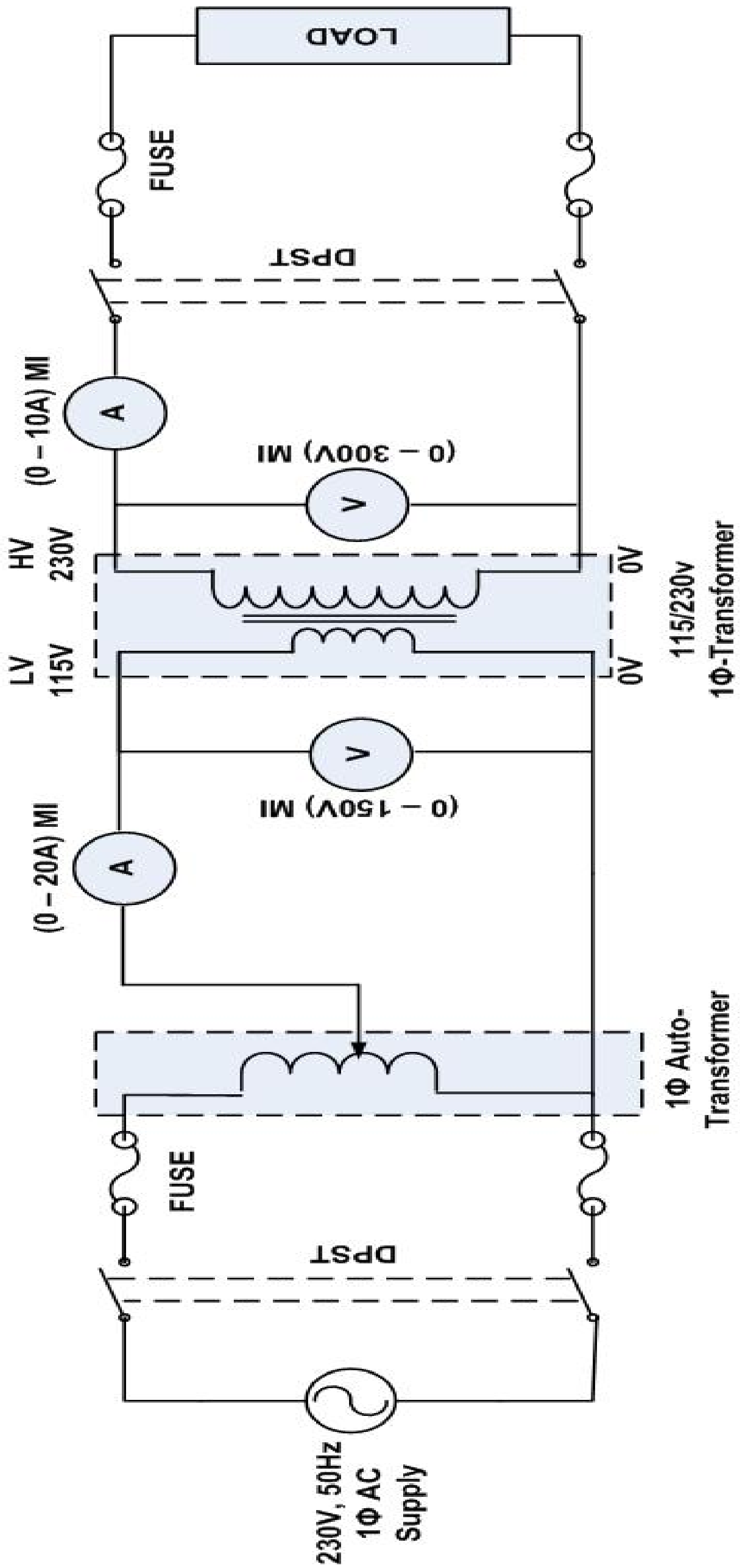
Sl. No	Applied Voltage V (Volts)	Current in amps I_L (Amps)	Time (Sec)	Electric Energy (Wh)
1				
2				
3				
4				
5				

Theoretical Caluculations:

Result:

6. TRANSFORMATION RATIO OF A SINGLE PHASE TRANSFORMER

Circuit diagram:



TRANSFORMATION RATIO OF A SINGLE PHASE TRANSFORMER

EXP. NO:
DATE:

Aim: Determine the current and voltage transformation ratio of a single phase transformer under no-load and full load.

Name Plate Details:

Rating	2 KVA
Low voltage	110V
High voltage	230V
Frequency	50Hz
Type of cooling	Natural

Apparatus:

Sl.No	Apparatus	Range	Type	Quantity
1	Transformer	115/230V, 2KVA	Single Phase	1
2	Voltmeter	(0 - 300 V)	MI	1
		(0 - 150 V)		1
3	Ammeter	(0 - 10 A)	MI	1
		(0 - 20 A)		1
4	Single Phase Load	13KW, 13 A	Resistive, Variable	1
5	Auto Transformer	230V/(0-270V),10A, 50Hz	Single phase	1

Procedure:

1. All the connections are made as per the circuit diagram.
2. Keep auto transformer in minimum voltage position.
3. Connect single phase supply by closing DPST switch.
4. Adjust auto transformer to get rated voltage across the transformer terminal.
5. Note down the volt meter reading.
6. Calculate transformation ratio from voltmeter readings
7. Load the transformer step by and note down the volt meter and ammeter readings at full load.
8. Calculate voltage transformation and current transformation ratio from voltmeter and ammeter readings
9. Switch off the power supply

Observations:

Readings at no-load:

S.No	Voltage(V)		Current (A) I_1	Voltage Transformation Ratio
	V_1	V_2		$K= V_2/V_1$

Readings with load on transformer:

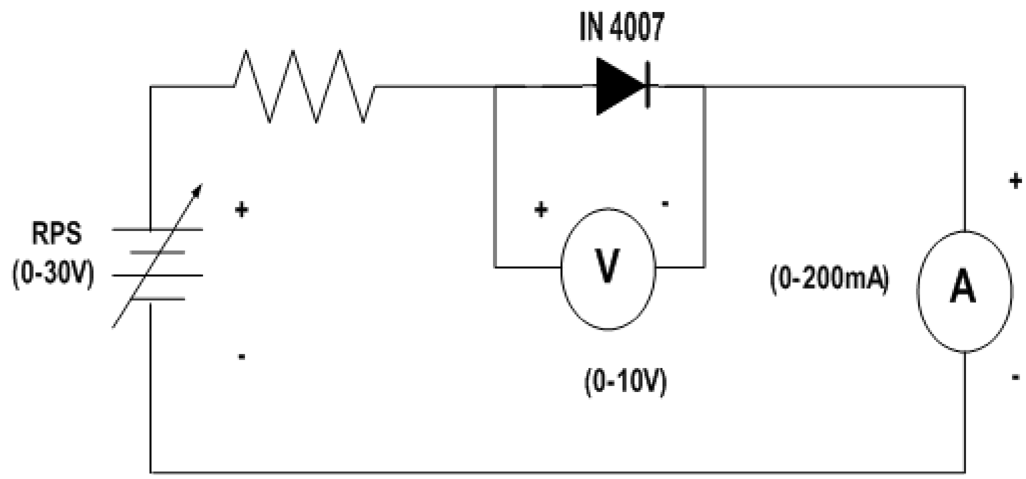
S.No	Voltage(V)		Current (A)		Voltage Transformation Ratio	Current Transformation Ratio
	V_1	V_2	I_1	I_2	$K= V_2/V_1$	$K= I_1/I_2$
1						
2						
3						

Result:

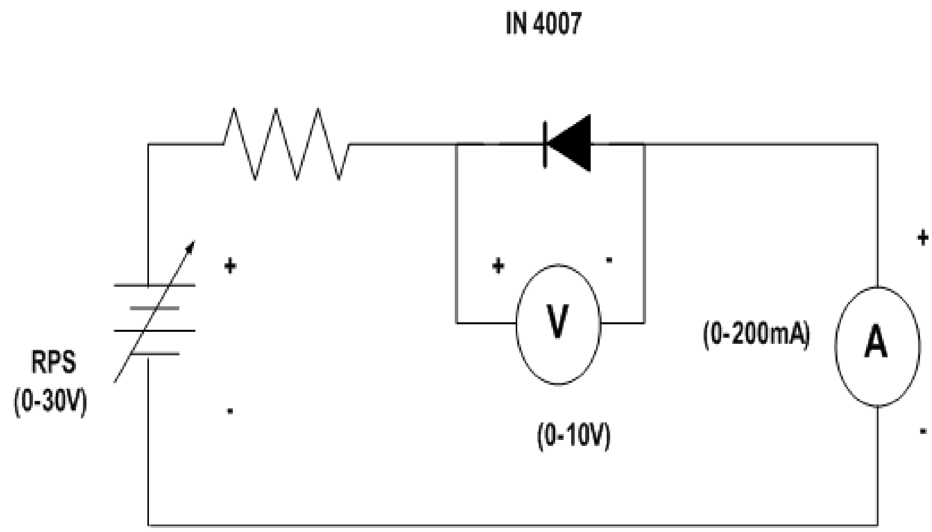
7. P-N Junction Diode

Circuit diagram:

Forward Bias:



Reverse Bias:



VI – CHARACTERISTICS OF P-N JUNCTION DIODE

EXP. No.:
DATE:

Aim: To draw the V-I Characteristics of the PN Junction diode under forward and reverse bias.

Apparatus:

S.No	Apparatus	Range	Quantity
1	Bread Board	.....	1
2	P-N Junction Diode	Model: IN4007	1
3	Regulated Power supply	(0-30v)	1
4	Resistor	---	1
5	Ammeter	(0-200 mA)	1
6	Voltmeter	(0-30 V)	1
7	Connecting wires	....	As Required

Procedure:

Forward Bias:

1. Connections are made as per the circuit diagram.
2. For forward bias, the RPS +ve is connected to the anode of the diode and RPS –ve is connected to the cathode of the diode,
3. Switch on the power supply and increases the input voltage (supply voltage) in Steps.
4. Note down the corresponding current flowing through the diode and voltage across the diode for each and every step of the input voltage.
5. The reading of voltage and current are tabulated.
6. Graph is plotted between voltage and current.

Reverse Bias:

1. Connections are made as per the circuit diagram.
2. For reverse bias, the RPS +ve is connected to the cathode of the diode and RPS –ve is connected to the anode of the diode.
3. Switch on the power supply and increase the input voltage (supply voltage) in Steps
4. Note down the corresponding current flowing through the diode voltage across the diode for each and every step of the input voltage.
5. The readings of voltage and current are tabulated
6. Graph is plotted between voltage and current.

Observation Tables:

Forward Bias:

S.No	Applied Voltage Across Diode(V)	PN-Diode Voltage(V_F)	Diode Current(I_F)
1	0.1		
2	0.2		
3	0.3		
4	0.4		
5	0.5		
6	0.6		
7	0.7		
8	0.8		
9	0.9		
10	1.0		
11	2.0		
12	3.0		
13	4.0		
14	5.0		
15	6.0		
16	7.0		
17	8.0		
18	9.0		
19	10.0		

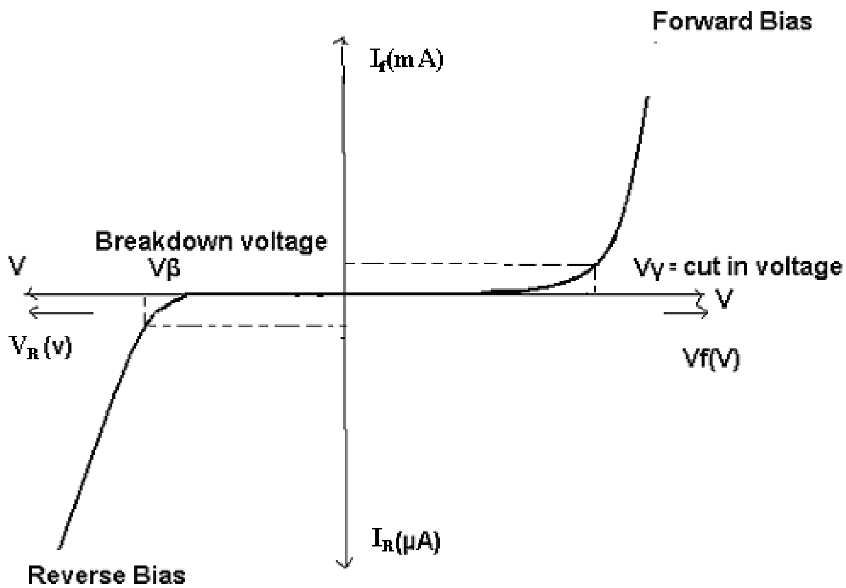
Cut-in Voltage =

Reverse Bias:

S.No	Applied Voltage Across Diode(V)	Diode Voltage(V_F)	Diode Current(I_F)
1	0.1		
2	0.2		
3	0.3		
4	0.4		
5	0.5		
6	0.6		
7	0.7		
8	0.8		
9	0.9		
10	1.0		
11	2.0		
12	3.0		
13	4.0		
14	5.0		
15	6.0		
16	7.0		
17	8.0		
18	9.0		
19	10.0		

Break Down Voltage =

Model Waveform:



Precautions:

1. All the connections should be correct.

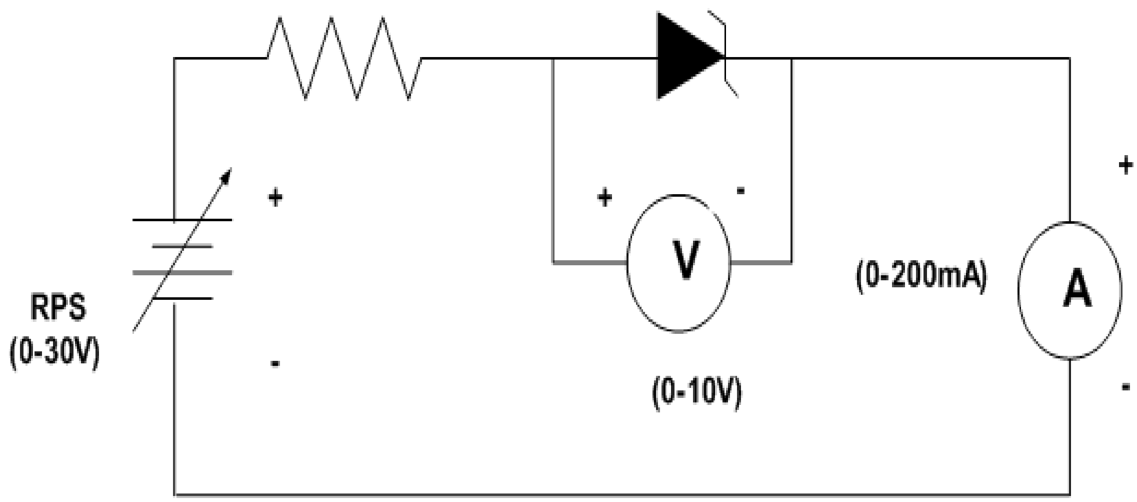
2. Parallax error should be avoided while taking the readings from the Analog meters.

Result:

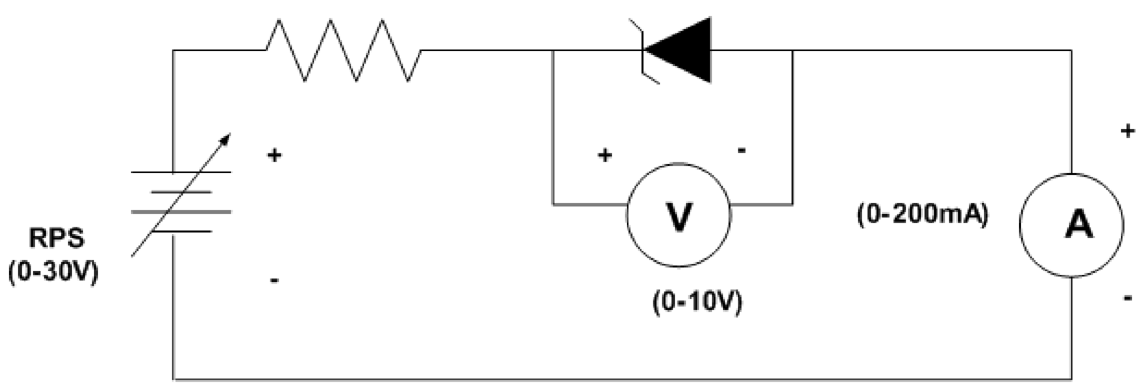
8. Zener Diode

Circuit Diagram:

Forward Bias:



Reverse Bias:



VI – CHARACTERISTICS OF Zenar DIODE

EXP. No.:
DATE:

Aim: To observe and draw the V-I Characteristics of the Zenar diode under forward and reverse bias.

Apparatus:

S.No.	Apparatus	Range	Quantity
1	Bread Board	....	1
2	Zener Diode	....	1
3	Regulated Power Supply	(0-30v)	1
4	Resistor	1KΩ	1
5	Ammeter	(0-200 mA)	1
6	Voltmeter	(0-10 V)	1
7	Connecting wires	....	As Required

Procedure:

Forward Characteristics:

1. Connections are made as per the circuit diagram.
2. The Regulated power supply voltage is increased in steps.
3. The zener current (l_z), and the zener voltage (V_z.) are observed and then noted in the tabular form.
4. A graph is plotted between zener current (I_z) and zener voltage (V_z).

Reverse characteristics:

1. Connections are made as per the circuit diagram.
2. The Regulated power supply voltage is increased in steps.
3. The zener current (l_z), and the zener voltage (V_z.) are observed and then noted in the tabular form.
4. A graph is plotted between zener current (I_z) and zener voltage (V_z).

Observation Tables:

Forward Characteristics:

S.No	Applied Voltage Across Diode(V)	Zener Diode Voltage(V_F)	Diode Current(I_F)
1	0.1		
2	0.2		
3	0.3		
4	0.4		
5	0.5		
6	0.6		
7	0.7		
8	0.8		
9	0.9		
10	1.0		
11	2.0		
12	3.0		
13	4.0		
14	5.0		
15	6.0		
16	7.0		
17	8.0		
18	9.0		
19	10.0		

Cut-in Voltage =

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Reverse Characteristics:

S.No	Applied Voltage Across Diode(V)	Zener Diode Voltage(V_F)	Diode Current(I_F)
1	0.1		
2	0.2		
3	0.3		
4	0.4		
5	0.5		
6	0.6		
7	0.7		
8	0.8		
9	0.9		
10	1.0		
11	2.0		
12	3.0		
13	4.0		
14	5.0		
15	6.0		
16	7.0		
17	8.0		
18	9.0		
19	10.0		

Break Down Voltage =

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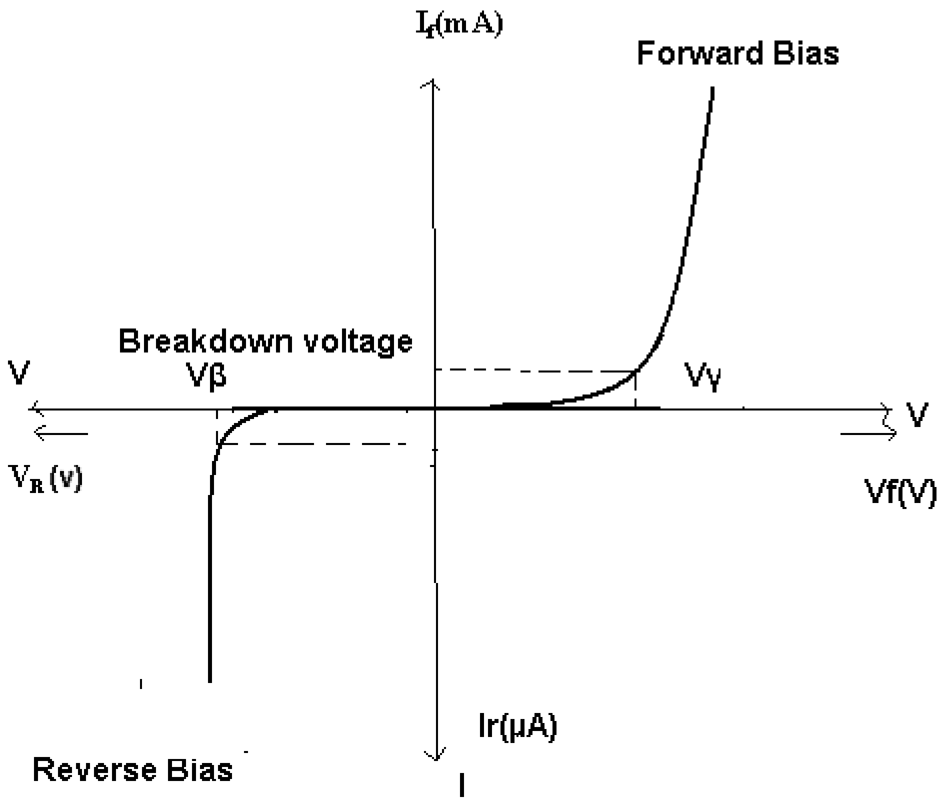
Model Waveforms:



Precautions:

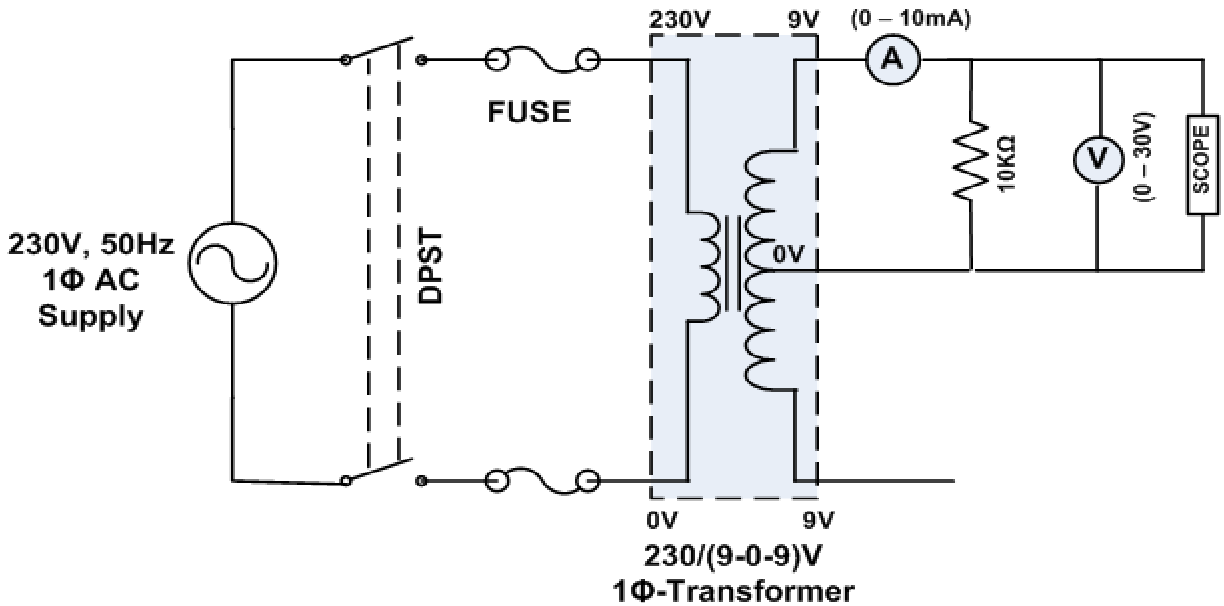
1. The terminals of the zener diode should be properly identified
2. While determined the load regulation, load should not be immediately shorted.
3. Should be ensured that the applied voltages & currents do not exceed the ratings of the diode.

Result:

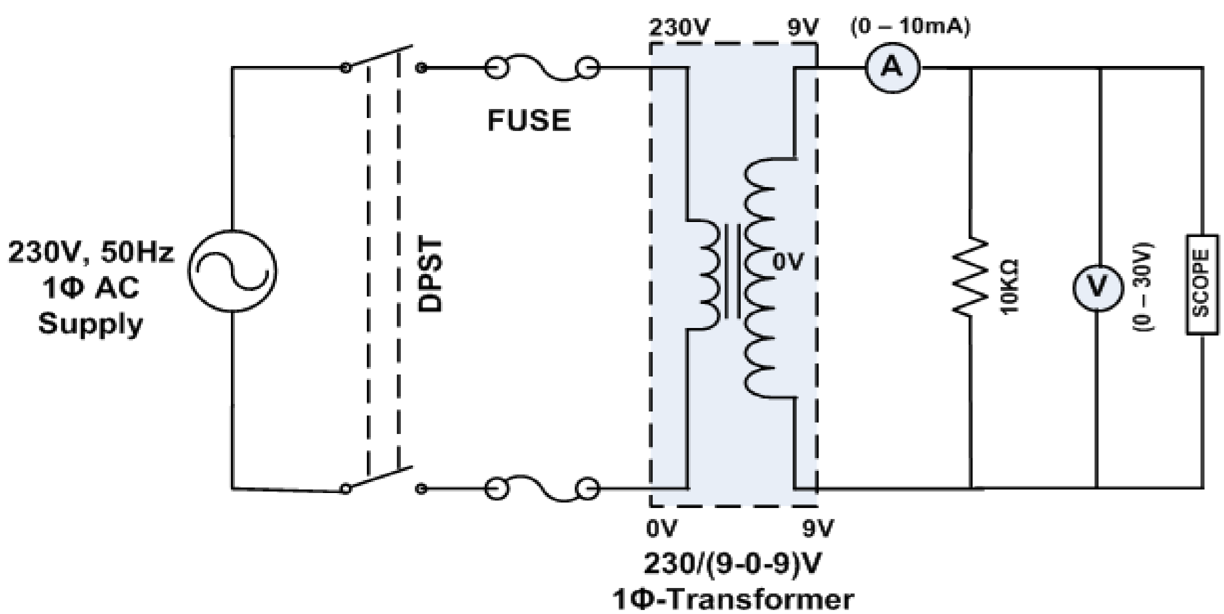
9. R.M.S VALUES OF VARIOUS WAVEFORMS

Circuit diagram:

Circuit-1



Circuit-2



DETERMINATION OF R.M.S VALUES OF VARIOUS WAVEFORMS

EXP. NO:
DATE:

Aim: i) Familiarization with function of function generator and oscilloscope.

ii) Measurement of root mean square value of Sinusoidal signal waveform.

Apparatus:

Sl.No	Apparatus	Quantity
1	Digital Multimeter	1
2	Centre-Tapped Transformer	1
3	Resistor $R_1 = 10K\Omega$	1
4	Bread Board	1
5	DSO	1

Procedure:

1. Connect the circuit as shown in the circuit diagram 1.
2. Switch on the supply.
3. Set the multimeter into AC mode and measure the voltage. This value gives RMS value of sinusoidal AC.
4. For average voltage measurement set multimeter into DC mode and measure the voltage.
5. Observe the AC voltage waveform in DSO and note down the peak to peak voltage.
6. Calculate the peak value, RMS and Average value.
7. Repeat the procedure by connecting the circuit as shown in diagram 2.

Observations from Circuit 1:

a. **From Multimeter:**

- Average Value =
- RMS Value =

b. **From DSO:**

- Peak to Peak Value =
- Peak Value =
- Average Value =
- RMS Value =

Observations from Circuit 2:

a. **From Multimeter:**

- Average Value =
- RMS Value =

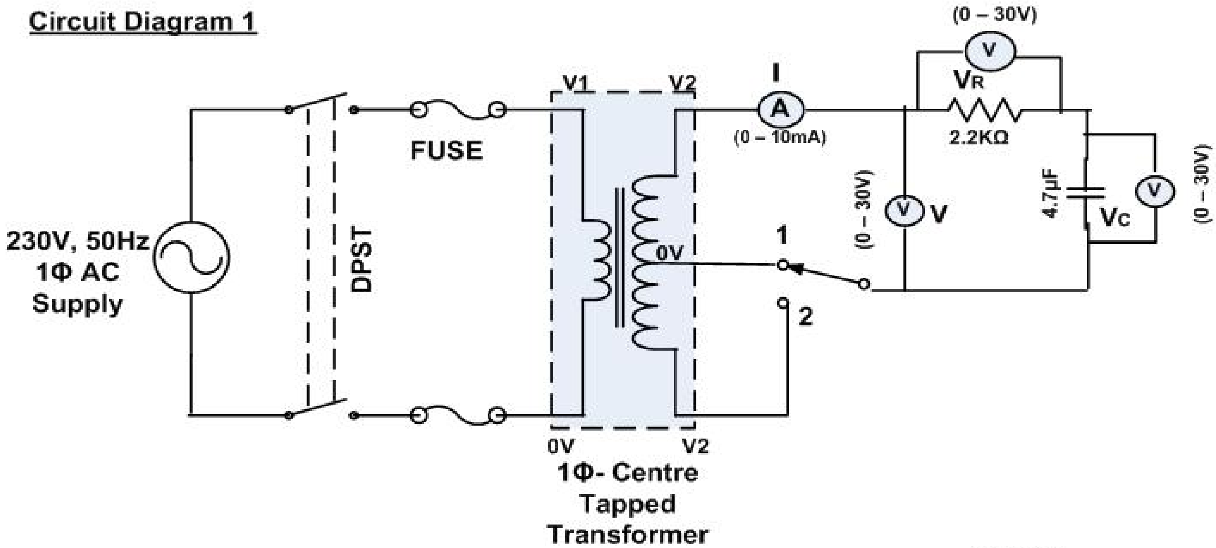
b. **From DSO:**

- Peak to Peak Value =
- Peak Value =
- Average Value =
- RMS Value =

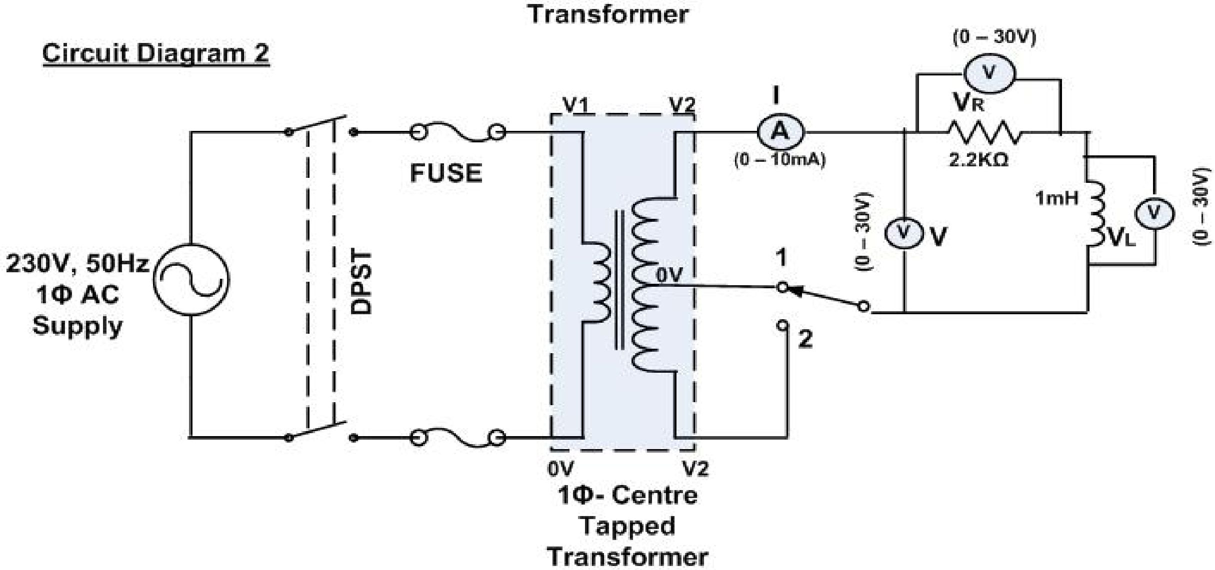
Result:

10. DETERMINATION OF IMPEDANCE IN COMPLEX AC CIRCUITS

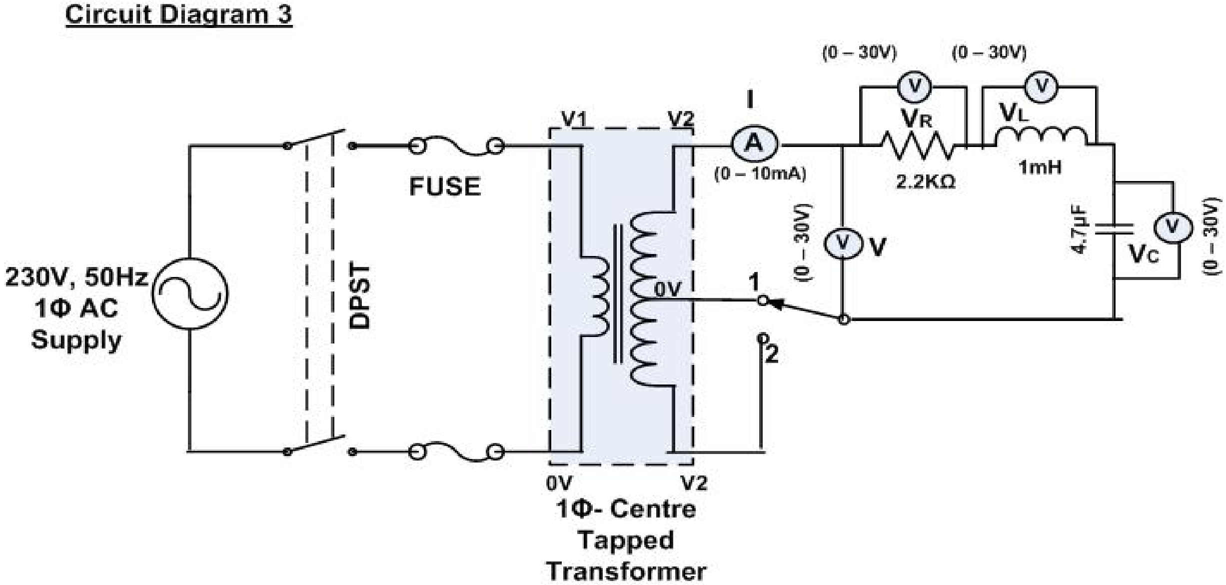
Circuit Diagram 1



Circuit Diagram 2



Circuit Diagram 3



DETERMINATION OF IMPEDANCE IN COMPLEX AC CIRCUITS

EXP. NO:
DATE:

Aim: To determine the impedance of single phase series RC, RL and RLC circuits.

Apparatus:

Sl.No	Apparatus	Quantity
1	Digital Multimeter	1
2	Centre-Tapped Transformer	1
3	Resistor $R = 2.2K\Omega$	1
4	Inductor $L = 1mH$	1
5	Capacitor $C = 4.7\mu F$	1
6	Bread Board	1

Procedure:

1. Connect the circuit as per the circuit diagram.
2. Keep switch position at 1 and switch on the power supply.
3. Note down all the voltmeter and ammeter readings.
4. Repeat the procedure by keeping the switch position at 2.
5. Calculate the unknown impedance value.

Observations:

Frequency (Hz) = 50Hz

1. **Series RC Circuit:**

S.No	Voltage, V (V)	Current, I (A)	Impedance $Z = \frac{V}{I}$ (Ω)	V_R (V)	V_C (V)	$R = \frac{V_R}{I}$ (Ω)	$X_C = \frac{V_C}{I}$ (Ω)	Impedance $Z = \sqrt{R^2 + (X_C)^2}$ (Ω)

2. **Series RL Circuit:**

S.No	Voltage, V (V)	Current, I (A)	Impedance $Z = \frac{V}{I}$ (Ω)	V_R (V)	V_L (V)	$R = \frac{V_R}{I}$ (Ω)	$X_L = \frac{V_L}{I}$ (Ω)	Impedance $Z = \sqrt{R^2 + (X_L)^2}$ (Ω)

3. **Series RLC Circuit:**

S.No	Voltage, V (V)	Current, I (A)	Impedance $Z = \frac{V}{I}$ (Ω)	V_R (V)	V_L (V)	V_C (V)	$R = \frac{V_R}{I}$ (Ω)	$X_L = \frac{V_L}{I}$ (Ω)	$X_C = \frac{V_C}{I}$ (Ω)	Impedance $Z = \sqrt{R^2 - (X_L - X_C)^2}$ (Ω)

Theoretical Calculation of Z (using given R, L, C values):

R =

L =

C =

1. **Series RC Circuit:**

$$\mathbf{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} =}$$

$$\mathbf{Z = \sqrt{R^2 + X_C^2} =}$$

2. **Series RL Circuit:**

$$\mathbf{X_L = \omega L = 2\pi f L =}$$

$$\mathbf{Z = \sqrt{R^2 + X_L^2} =}$$

3. **Series RLC Circuit:**

$$\mathbf{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} =}$$

$$\mathbf{X_L = \omega L = 2\pi f L =}$$

$$\mathbf{Z = \sqrt{R^2 + (X_L - X_C)^2} =}$$

Result: