

**SCHEME : K**

Name : \_\_\_\_\_  
Roll No. : \_\_\_\_\_ Year : 20\_\_ 20\_\_  
Exam Seat No. : \_\_\_\_\_

# LABORATORY MANUAL FOR ELECTRONIC MATERIALS & COMPONENTS (312316)



**ELECTRONICS ENGINEERING GROUP**



**MAHARASHTRA STATE BOARD OF  
TECHNICAL EDUCATION, MUMBAI  
(Autonomous) (ISO 9001: 2015) (ISO/IEC 27001:2013)**

## VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

## MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the changing technological and environmental challenges.

## QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

## CORE VALUES

MSBTE believes in the followings:

- Education industry produces live products.
- Market requirements do not wait for curriculum changes.
- Question paper is the reflector of academic standards of educational organization
- Well-designed curriculum needs effective implementation too.
- Competency based curriculum is the backbone of need based program.
- Technical skills do need support of life skills.
- Best teachers are the national assets.
- Effective teaching learning process is impossible without learning resources.

**A Laboratory Manual**  
**for**  
**Electronic Materials &**  
**Components**  
**(312316)**  
**Semester-II**  
**(DE/ EJ/ ET/ EX/ IE/ MU)**



**Maharashtra State**  
**Board of Technical Education, Mumbai**  
**(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)**



**Maharashtra State**  
**Board of Technical Education, Mumbai**  
**(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)**  
4th Floor, Government Polytechnic Building, 49, Kherwadi,  
Bandra (East), Mumbai - 400051.



**MAHARASHTRA STATE  
BOARD OF TECHNICAL EDUCATION**

**Certificate**

This is to certify that Mr. / Ms. ....  
Roll No.....of      Second Semester of    Diploma in .....  
..... of Institute .....  
(Code: .....) has attained pre-defined practical outcomes (PROs)  
satisfactorily in course **Electronic Materials & Components (312316)** for  
the academic year 20..... to 20.....as prescribed in the curriculum.

Place: .....

Enrollment No: .....

Date: .....

Exam. Seat No: .....

**Course Teacher**

**Head of the Department**

**Principal**



## Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative ‘K’ Scheme curricula for engineering diploma programmes with outcome-based education as the focus and accordingly, a relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work, making each teacher, instructor and student realize that every minute of the laboratory time needs to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ‘*vehicle*’ to develop this industry identified competency in every student. The practical skills are difficult to develop through ‘chalk and duster’ activity in the classroom situation. Accordingly, the ‘K’ scheme laboratory manual development team designed the practicals to *focus* on the *outcomes*, rather than the traditional age old practice of conducting practicals to ‘verify the theory’ (which may become a byproduct along the way).

This laboratory manual is designed to help all stake holders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through the procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The course Electronic Materials & Components (312316) is intended to help the students of Diploma Engineering to get an idea of various Electronic Materials and Components employed in electronic industries. It will make the students familiar with the suitability of various electronic materials and components for different applications. This course is intended to develop skills of testing components that will be needed for the project and setting up of many experiments in basic and applied technology courses.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

## **Programme Outcomes (POs) and Program Specific Outcomes (PSOs) to be achieved through Practicals of this Course**

Following programme outcomes are expected to be achieved through the practical of the course.

**PO1: Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the broad based Electronics & Communication engineering problems.

**PO2: Problem analysis:** Identify and analyze well-defined Electronics & Communication engineering problems using codified standard methods.

**PO3: Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of Electronics & Communication systems components or processes to meet specified needs.

**PO4: Engineering Tools, Experimentation and Testing:** Apply modern Electronics & Communication engineering tools and appropriate technique to conduct standard tests and measurements.

**PO5: Engineering practices for society, sustainability and environment:** Apply appropriate Electronics & Communication technology in context of society, sustainability, environment and ethical practices.

**PO6: Project Management:** Use Electronics & Communication engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

**PO7: Life-long learning:** Ability to analyze individual needs and engage in updating in the context of Electronics & Communication technological changes.

**Program Specific Outcomes (PSOs)** (What s/he will be able to do in the Electronics engineering specific industry soon after the diploma programme)

**PSO1: Electronics and Telecommunication Systems:** Maintain various types of Electronics & Telecommunication systems

**PSO2: EDA Tools Usage:** Use EDA Tools to develop simple Electronics and Telecommunication Engineering related circuits.

### **List of Industry Relevant Skills**

The following industry relevant skills of the competency “Use of various Electronic Materials and Components for relevant electronic applications” are expected to be developed in the student by undertaking the practical of this laboratory manual

1. Identify the electronic component.
2. Test electronic component
3. Select the electronic component of proper value as per the requirement.
4. Mount the electronic component on the breadboard as per circuit diagram.
5. Test the circuit for the given application.
6. Compare the observed output with the expected output.



### Practical- Course Outcome matrix

<b>Course Outcomes (COs)</b>						
CO1- Identify the relevant material for the Electronic Applications.						
CO2- Suggest relevant electronic component(s) for the given application.						
CO3- Identify the Surface Mount Devices for specific applications.						
CO4- Develop the PCB for the given application.						
CO5- Use specific components for roof top Solar Energy Systems						
Sr. No.	Title of the Practical	CO 1	CO 2	CO 3	CO 4	CO 5
1.	Determination of resistivity	✓	-	-	-	-
2.	Determination of photoelectric cell characteristics	✓	-	-	-	-
3.	Charging and discharging curve of two different capacitors	✓	-	-	-	-
4.	Identification of various electronic components in the given circuit	-	✓	-	-	-
5.	LDR as a Dark Sensor	-	✓	-	-	-
6.	Reverse Bias Characteristic of Photo- Diode	-	✓	-	-	-
7.	Testing of different IC	-	✓	-	-	-
8.	Determination of SMD component value	-	-	✓	-	-
9.	Soldering of SMD	-	-	✓	-	-
10.	Identification of given SMD	-	-	✓	-	-
11.	Test any small electronic circuit/system	-	-	-	✓	-
12.	Use of open source PCB design simulation software and tools.	-	-	-	✓	-
13.	Identify types of PCB	-	-	-	✓	-
14.	Characteristics of the solar cell.	-	-	-	-	✓
15.	Use of Solar Panel to drive any small load	-	-	-	-	✓
16.	Voltage and current measurement using series and parallel connection of batteries	-	-	-	-	✓

### **Guidelines to Teachers**

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each practical.
3. Involve students in the performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in the students after the completion of the practical exercise.
5. Teachers should give opportunities to students for hands-on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected of the students by the industry.
8. Finally give practical assignments and assess the performance of students based on tasks assigned to check whether it is as per the instructions.
9. Teacher is expected to refer complete curriculum document and follow guidelines for implementation
10. At the beginning of the practical which is based on the simulation, teacher should make the students acquainted with any simulation software environment.

### **Instructions for Students**

1. Listen carefully to the lecture given by the teacher about course, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make a record of all observations.
3. Do the calculations and plot the graph wherever it is required in the practical
4. Students shall develop maintenance skills as expected by industries.
5. Student shall attempt to develop related hand-on skills and gain confidence.
6. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual
7. Student should develop the habit to submit the practical on date and time.
8. Student should prepare well while submitting a write-up of exercise.

## Content Page

### List of Practicals and Progressive Assessment Sheet

Sr. No.	Title of the practical	Page No.	Date of performance	Date of submission	Assessment marks(25)	Dated sign. Of teacher	Remarks (if any)
1.	Determination of resistivity	1					
2.*	Determination of photoelectric cell characteristics	9					
3.	Charging and discharging curve of two different capacitors	17					
4.*	Identification of various electronic components in the given circuit	26					
5.*	LDR as a Dark Sensor	37					
6.	Reverse Bias Characteristic of Photo- Diode	43					
7.	Testing of different IC	52					
8.*	Determination of SMD component value	62					
9.	Soldering of SMD	69					
10.*	Identification of given SMD	76					
11.*	Test any small electronic circuit/system	82					
12.*	Use of open source PCB design simulation software and tools.	91					
13.	Identify types of PCB	113					
14.*	Characteristics of the solar cell.	124					
15.	Use of Solar Panel to drive any small load	133					
16.	Voltage and current measurement using series and parallel connection of batteries	139					
<b>Total</b>							

## Practical No.1: Determination of resistivity

### I Practical significance:

The property of a material by which it offers an opposition in the flow of current is called resistivity. Metals are good conductors of electricity; hence they have low resistivity. Insulators are bad conductors of electricity; hence they have very high resistivity. Resistivity of a material is used in various applications such as quality control test, selection of right material for manufacturing of a resistor for a specific use etc.

### II Industry / Employer Expected outcome(s)

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

### III Course Level Learning outcome(s)

Identify the relevant material for the Electronic Applications.

### IV Laboratory Learning outcome(s)

Determine resistivity for a given length of wire keeping area constant.

### V Relevant Affective Domain related outcome(s)

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

### VI Relevant Theoretical Background

**Resistivity** of a material is defined as the resistance between the two opposite faces of a meter cube of that material.

Also, **Resistivity** is equal to resistance of a wire of unit length and unit cross sectional area of that material.

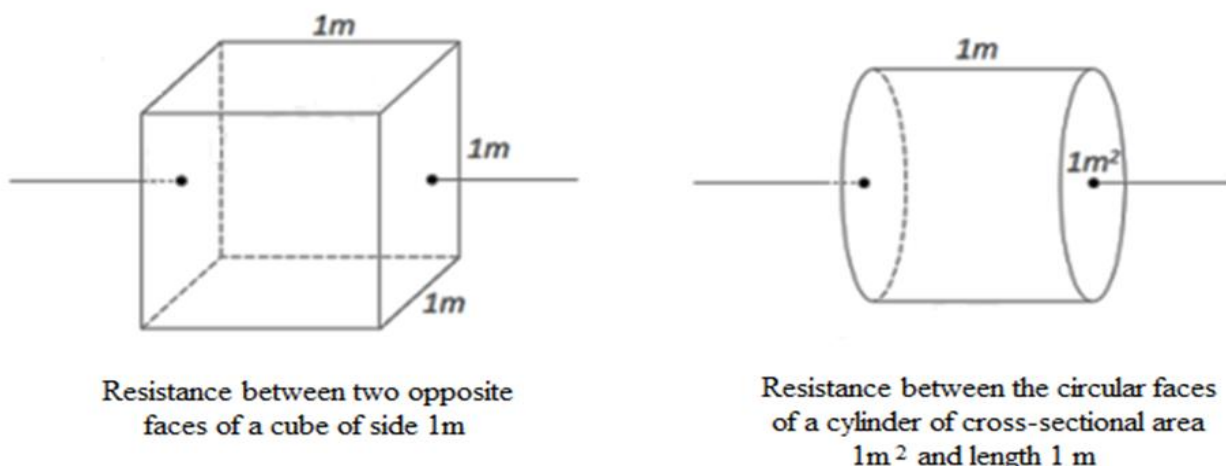


Figure 1.1: Concept of Resistivity

At a constant temperature, the resistance (R) of a given conductor is directly proportional to its length (L) and inversely proportional to its cross-sectional area (A).

**Resistivity** of the material of the coil of wire ( $\rho$ ) is,

$$\rho = \frac{RA}{L}$$

Where R is the resistance of the coil of wire (ohm)

A is the area of cross section of the wire (m<sup>2</sup>)

L is the length of the coil of wire (m)

Unit of **resistivity** is  $\Omega$ -m.

Factors which affect resistivity are temperature, alloying, cold work and age hardening.

Dependence of wire resistance on its length is as shown in Figure 1.2.

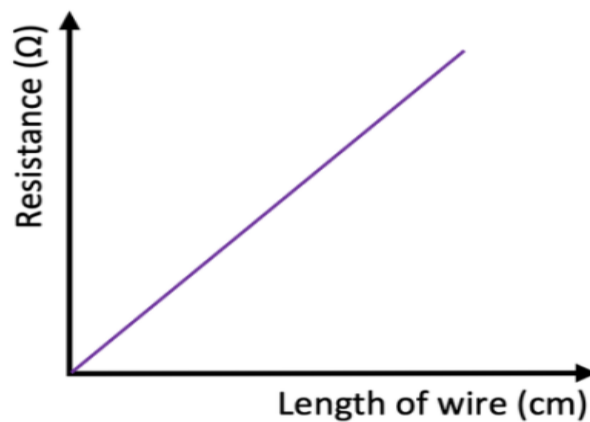


Figure 1.2: Graph of Resistance Vs. Wire length of wire

**VII Actual Circuit diagram used in laboratory with equipment specifications.**

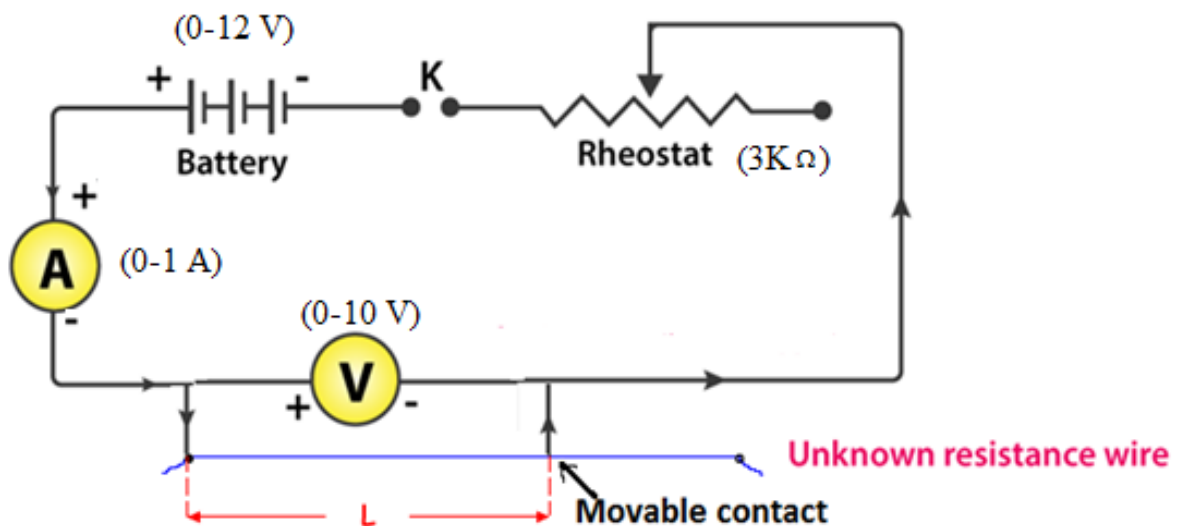


Figure 1.3: Determination of resistivity

**VIII Required Resources/apparatus/equipment with specifications.**

Sr. No.	Instrument /Components	Specification	Quantity	Remark
1	Voltmeter	0-10V	1	
2	Ammeter	0-1A	1	
3	Battery	0-12V	1	
4	Wire sample	100 cm length	1	
5	Rheostat	3K $\Omega$	1	
6	Meter stick or Ruler	1-meter length	1	
7	Micrometer Screw Gauge	25x1/100 mm, 0.01mm	1	

**IX Precautions to be followed:**

1. Do not switch on the power supply unless you have checked the circuit connections as per the circuit diagram.
2. Connect voltmeter and ammeter in correct polarities.
3. All electrical connections should be neat and tight.

**X Procedure:**

1. Connect the battery, ammeter, given wire, rheostat and key in series, as shown in the circuit diagram.
2. Connect the voltmeter in parallel to the unknown resistance wire.
3. Close the key and hence the circuit is closed.
4. Measure the length of the wire using meter scale
5. Measure voltage across the wire with a voltmeter and the current through the wire with an ammeter.
6. Tabulate the observations.
7. Calculate resistance of a wire as  $R=V/I$ .
8. Vary the length of the wire (from say 25 cm to 100 cm in 25 cm intervals) using moving contact (crocodile pin can be used)
9. Adjust the variable resistor to keep a low fixed current flowing through the wire (to minimize errors from heating effect)
10. Repeat step 4 to 7 for different lengths of wire.
11. Measure the diameter of the wire using a micrometer screw gauge.
12. Calculate the cross-sectional area as  $A = \pi*d^2/4$ .
13. Calculate resistivity of material of given wire as  $\rho=R*A/L$ .
14. Plot a graph of resistance R in  $\Omega$  on the y-axis against length L in cm on the x-axis.

**XI Observation table:**

**Table 1: Determination of resistivity**

Sr. No	Length(m)	Current(A)	Voltage(V)	Resistance( $\Omega$ )	Resistivity( $\Omega$ -m)
1					
2					
3					
4					
<b>Mean value</b>					

**Calculations:**

1. Resistance of wire as  $R=V/I=$  \_\_\_\_\_  $\Omega$
2. Diameter of the wire,  $d =$  \_\_\_\_\_ m
3. Area of cross section of the wire,  $A = \pi*d^2/4 =$  \_\_\_\_\_  $m^2$
4. Length of the wire  $L =$  \_\_\_\_\_ m.
5. Resistivity of the material of the wire  $\rho =R*A/L =$  \_\_\_\_\_  $\Omega m$

**XII Result(s)**

Observe the plotted graph and write:

1. Resistivity of a given wire, keeping cross sectional area constant =..... $\Omega m$ .
2. As length of wire increases, resistance of wire ..... (increases / decreases).

**XIII Interpretation of results**

.....  
 .....

**XIV Conclusions and recommendation:**

.....  
 .....







**XVI References/Suggestions for further reading: include websites/links**

1. [https://en.wikipedia.org/wiki/Electrical\\_resistivity\\_and\\_conductivity](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity)
2. [https://www.electronics-notes.com/articles/basic\\_concepts/resistance/electrical-resistivity.php](https://www.electronics-notes.com/articles/basic_concepts/resistance/electrical-resistivity.php)
3. <https://www.digimat.in/nptel/courses/video/105103182/L11.html>

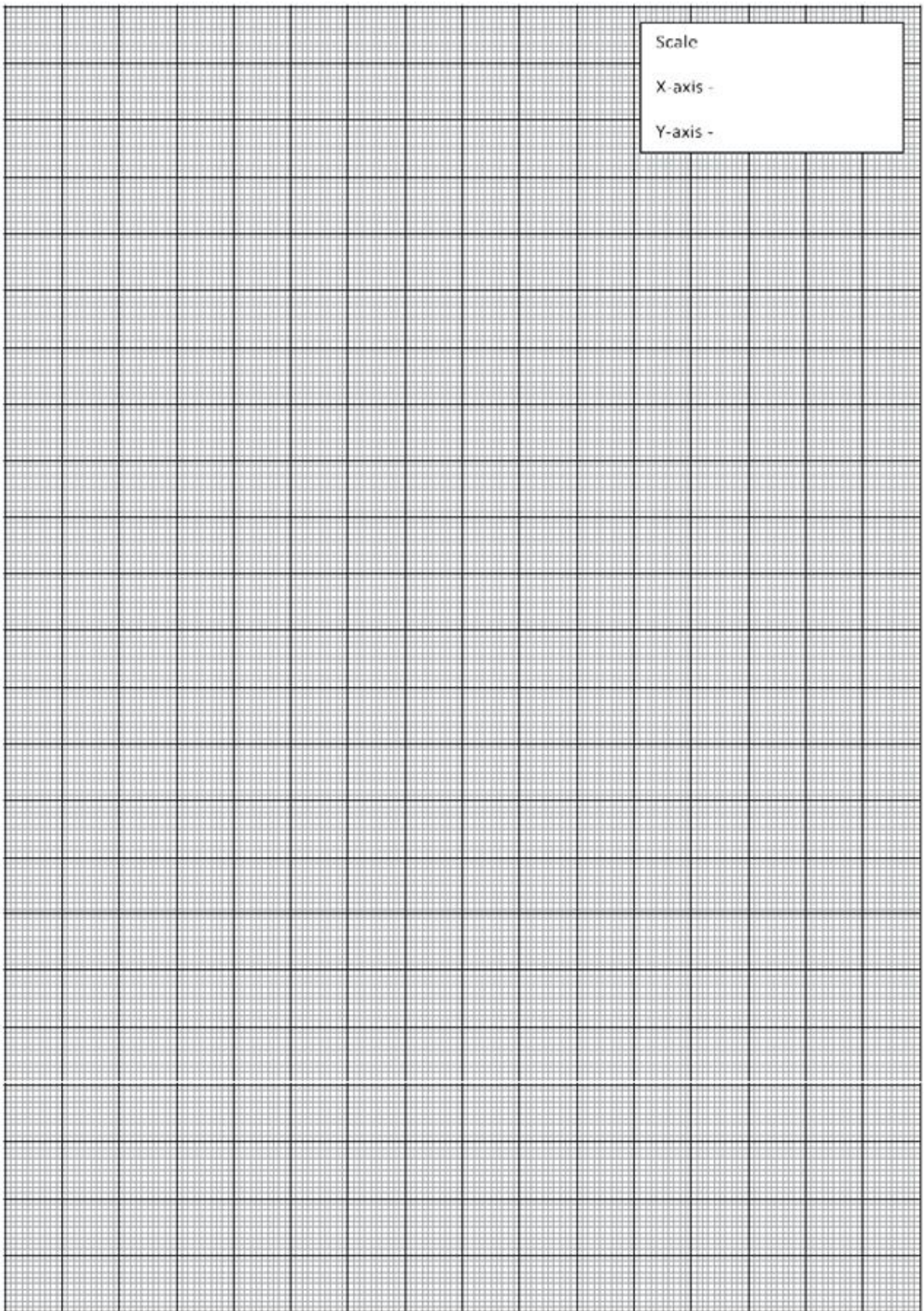
**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	



## Practical No.2: Determination of photoelectric cell characteristics

### I Practical significance:

The main function of a photocell is photoelectric detection which can convert light signals into electrical signals under the condition of no bias voltage. Due to numerous advantages like wide linear range, high sensitivity, spectral response, appropriate good stability and long service life. Photoelectric cells are widely used in precision measurement. For obtaining accurate results, study of photoelectric cell characteristics is essential.

### II Industry / Employer Expected outcome(s)

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

### III Course Level Learning outcome(s)

Identify the relevant material for the Electronic Applications.

### IV Laboratory Learning outcome(s)

Use photo electric cell to study I-V characteristics.

### V Relevant Affective Domain related outcome(s)

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

### VI Relevant Theoretical Background

A device used to convert light energy into electrical energy is called Photoelectric Cell.

Photocell is based on the phenomenon of Photoelectric effect. Photocells are of three types.

1. Photo-Emissive Cell.
2. Photo-Voltaic Cell.
3. Photo-Conductive Cell.

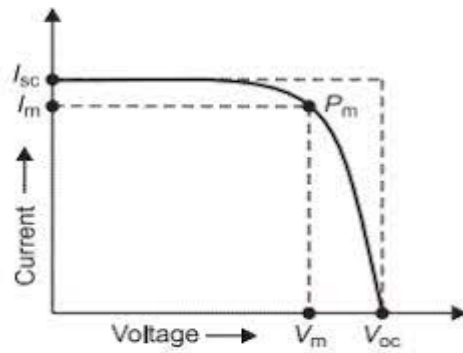
All three types of photoelectric cell can detect light or convert it into electricity.

The important observations on Photoelectric effect are:

- The Photoelectric effect is an instantaneous phenomenon. There is no time delay between the incidence of light and emission of photoelectrons.
- The number of photoelectrons emitted is proportional to the intensity of incident light.
- Energy of emitted photoelectrons is independent of the intensity of incident light. Also, the energy of emitted photoelectrons is directly proportional to the frequency of incident light.

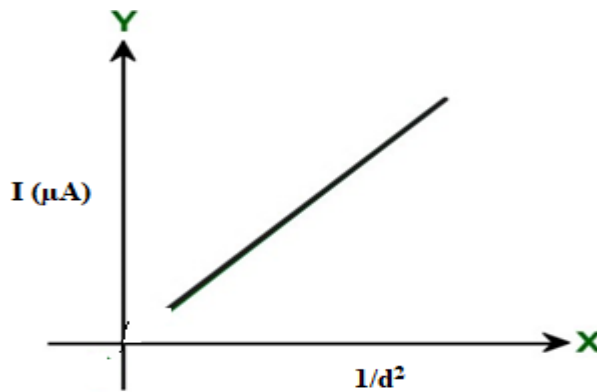
**Characteristic Curve:**

1. Current (I) vs Voltage (V)



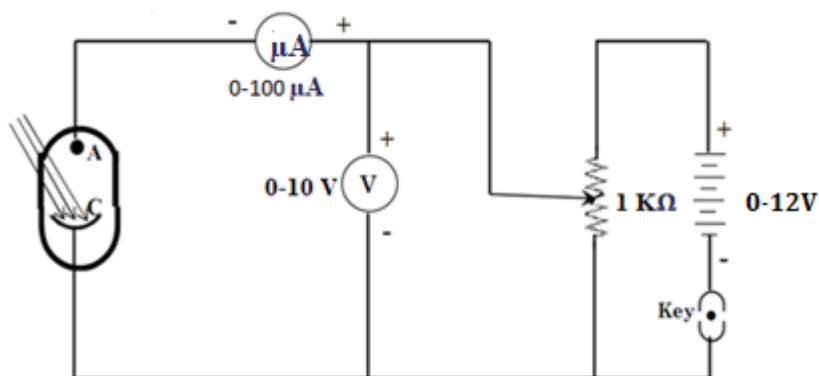
**Figure 2.1: Plot of Current ( I ) vs Voltage (V)**

2. Current ( I ) vs  $1/d^2$



**Figure 2.2: Plot of Current ( I ) vs  $1/d^2$**

**VII Actual Circuit diagram used in laboratory with equipment specifications.**



**Figure 2.3: Circuit diagram of photoelectric cell characteristics**

**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instrument / Components	Specification	Quantity	Remark
1	Photocell	Selenium, mounted in the metal box	1	
2	Micro ammeter	0-100 $\mu$ A	1	
3	Variable power supply	(0 -12V), 500mA	1	
4	Light source	12V/35W tungsten lamp	1	
5	Voltmeter	0-10 V	1	
6	Scale	0-30cm	1	

**IX Precautions to be followed**

1. Stray light should be avoided.
2. Very sensitive micro ammeter should be used.

**X Procedure:**

Connect the apparatus as shown in the circuit diagram.

1. Keep the distance between lamp and photocell constant and record the current for different voltages.
2. Now keep the applied voltage to the photocell constant and record the currents for different values of distances.
3. Plot the following graphs showing characteristic curves of the photocell,
  1. Current (I) vs Voltage (V)
  2. Current (I) vs  $1/d^2$

**XI Observation table**

**Table 1: Current reading for different voltages.**

Distance between lamp and photocell = 20 cm

Sr. No	Voltage (V)	Current ( $\mu$ A)
1	2	
2	4	
3	6	
4	8	
5	12	

**Table 2: Current reading for different values of distances.**

Applied voltage to the photocell = 8 V

Sr. No	Distance 'd' (cm)	Current ( $\mu\text{A}$ )	$1/d^2$
1	2		
2	4		
3	6		
4	8		
5	12		

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation:**

.....  
.....

**XV Practical related questions**

1. Define a photocell. Give the types of photocell.
2. State photo- electric effect.
3. List the materials used for the construction of a photocell.
4. Give two applications of photocells.

**Answers:**

.....  
.....  
.....  
.....  
.....





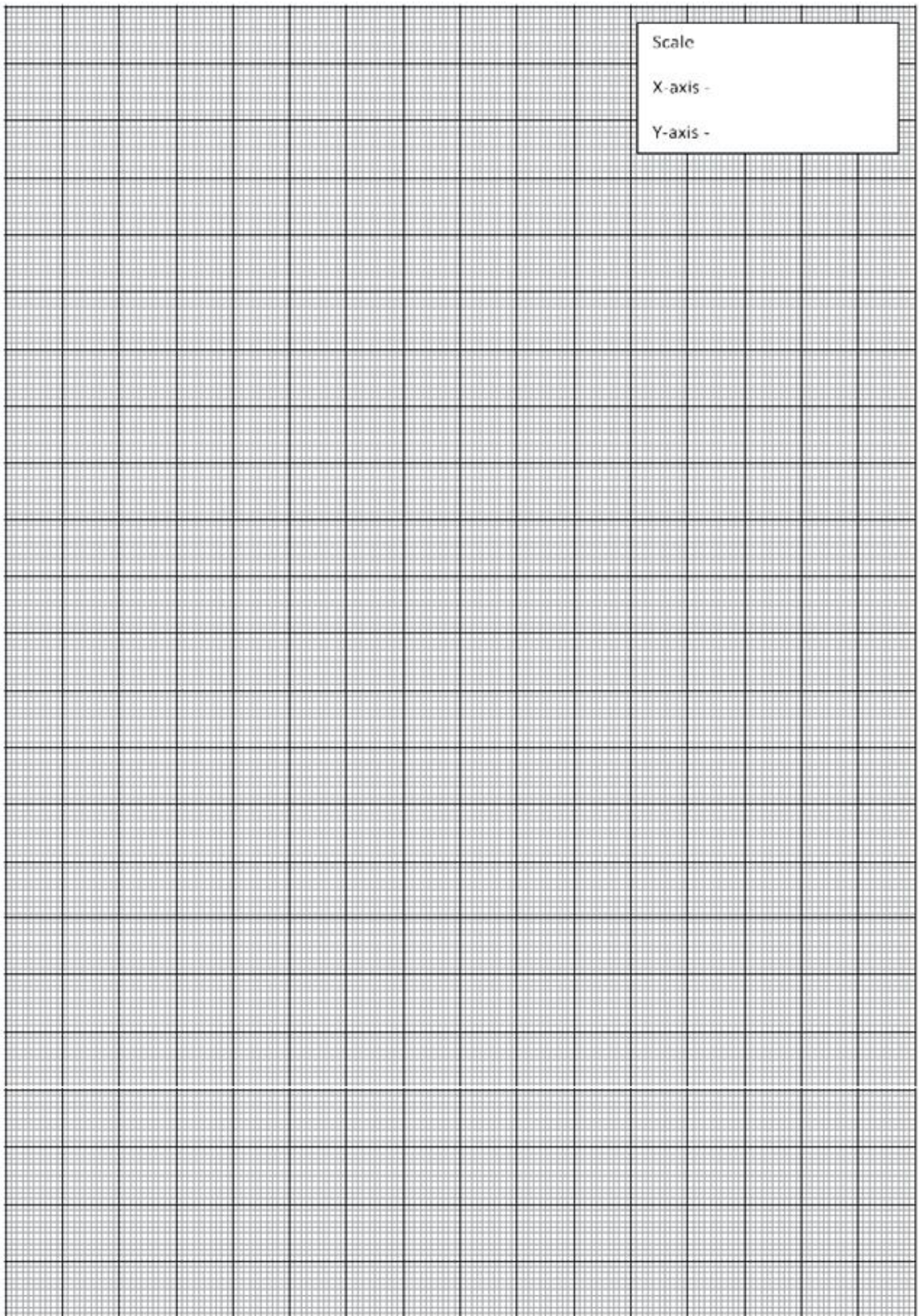
**XVII Assessment Scheme**

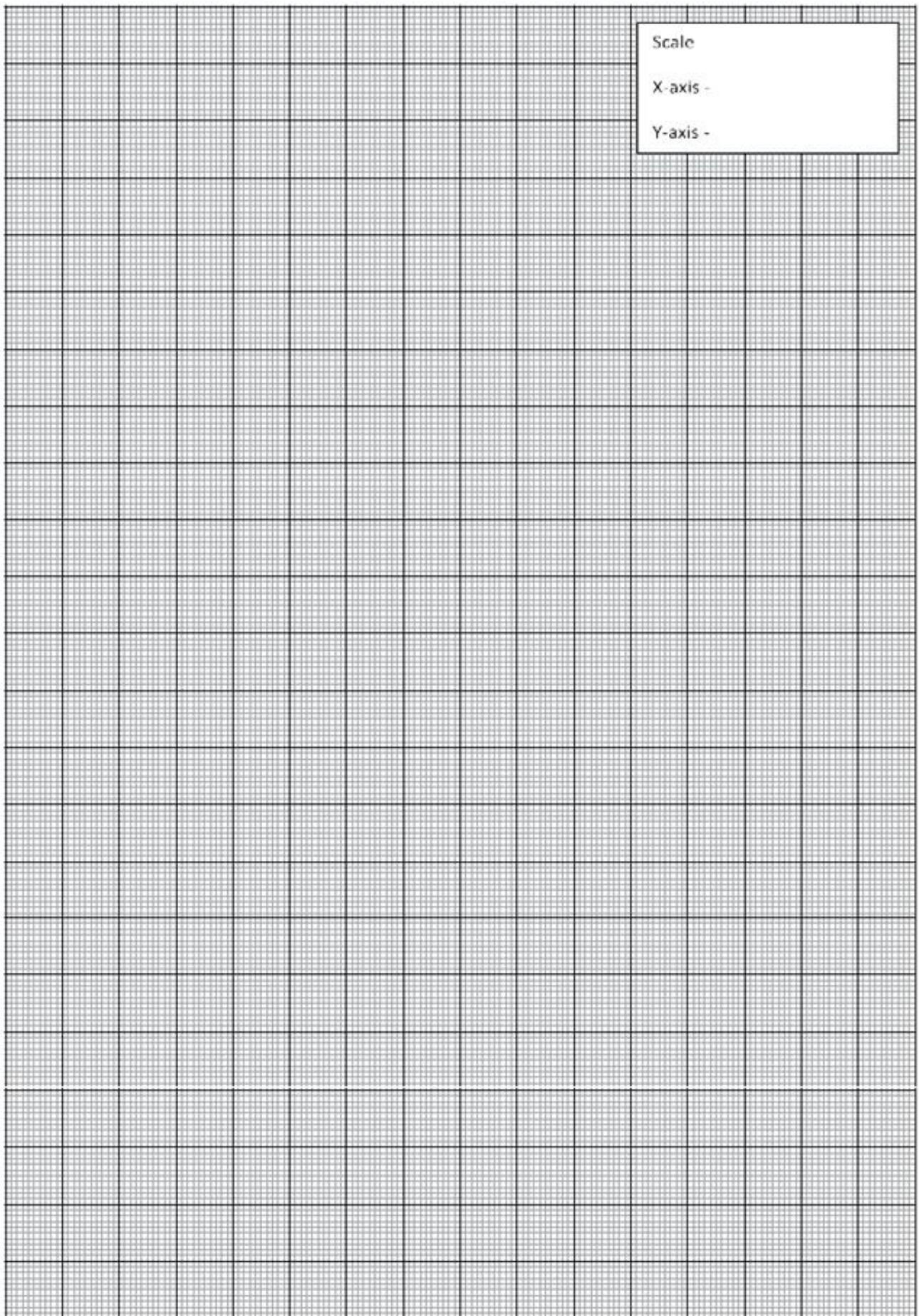
<b>Performance indicators</b>		<b>Weightage</b>
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

<b>Marks Obtained</b>			<b>Dated Sign of Teacher</b>
<b>Process Related(15)</b>	<b>Product Related(10)</b>	<b>Total (25)</b>	





**Practical No.3: Charging and discharging curve of two different capacitors.****I Practical Significance:**

Understanding charging and discharging curves of capacitors with different dielectric materials is essential in exploring the effects of dielectric on the performance of capacitors. This experiment aims to provide insights into time constants and behaviour of capacitors with distinct dielectric properties.

**II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Identify the relevant material for the Electronic Applications.

**IV Laboratory Learning outcome(s)**

Plot the charging and discharging curve of two different capacitors each having different dielectric material.

**V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

**VI. Relevant Theoretical Background**

**Capacitor-**A capacitor is formed by keeping two metallic plates parallel to each other. By applying a potential across the two plates, an electric field is produced between the two plates. By placing an electrically insulated material within the plates the capacitance can be increased. The resulting capacitance of the parallel plate capacitor is given by,

$$C = \frac{k\epsilon_0 A}{d} \dots\dots(1)$$

where, C is the capacitance in Farad.

k is the dielectric constant.

$\epsilon_0$  is the permittivity  $8.85 \times 10^{-12}$  F/m

A is the area of the plate.

d is the distance between the plates or thickness of the dielectric material.

**Charging and Discharging of a capacitor-**

A capacitor can be charged using a resistor and a DC source. The capacitor will charge exponentially. The instantaneous voltage across the capacitor during charging is given by,

$$V = V_{\max} [1 - e^{-(t/RC)}] \dots\dots (2)$$

When the capacitor discharges through R, the voltage across the capacitor starts decreasing until it becomes zero. The instantaneous voltage across the capacitor during discharge is given by ,

$$V = V_{\max} [e^{-(t/RC)}] \dots\dots\dots (3)$$

where, R is resistance in ohms.

C is capacitance in farad.

t is the instantaneous time.

$V_{\max}$  is the maximum voltage to which the capacitor is charged.

Capacitor charging and discharging curves are as shown in figure 3.1 and 3.2 respectively. RC time constant ( $\tau$ ) is the product of circuit resistance (R) and circuit capacitance (C).

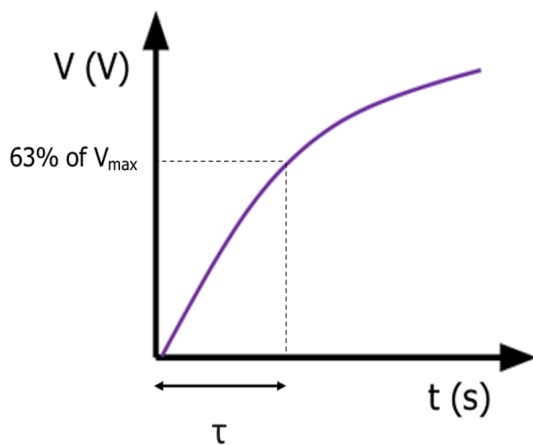


Figure 3.1: Capacitor charging curve

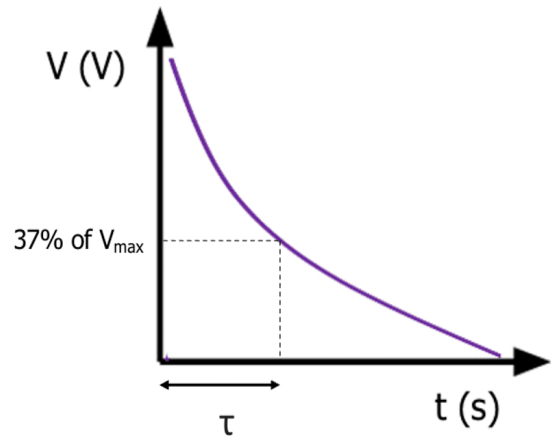


Figure 3.2: Capacitor discharging curve

**VII Actual Circuit diagram used in laboratory with equipment specifications.**

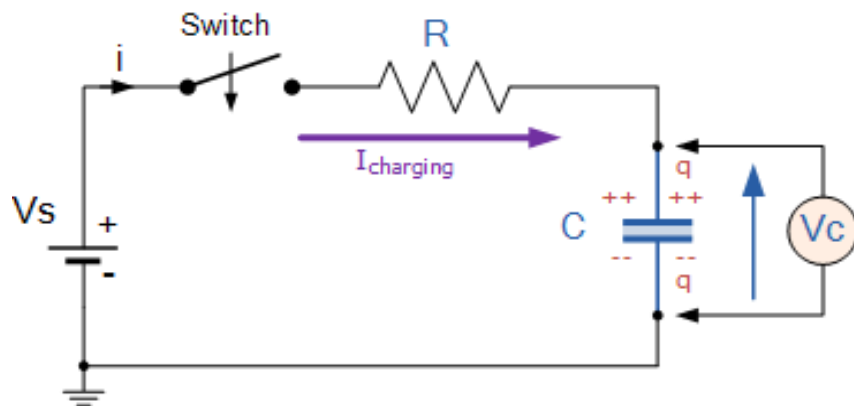


Figure 3.3: RC charging circuit

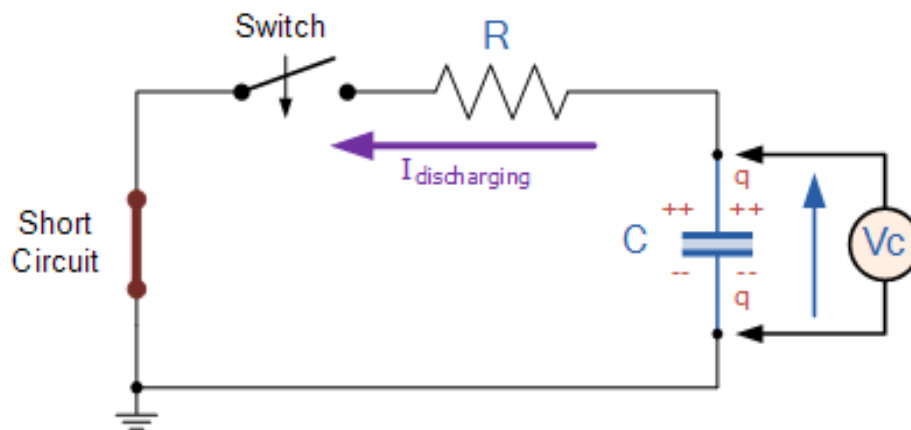


Figure 3.4: RC discharging circuit

### VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Instrument/ Components	Specification	Quantity	Remark
1	Breadboard	5.5cm 17cm	1	
2	Resistor	100 K $\Omega$	1	
3	Capacitor	220 $\mu$ F (different dielectrics)	2	
4	Multimeter/Voltmeter	3 ½ digit display/(0-20V)	1	
5	Power Supply	0-10 V	1	
6	Stop watch	0.1 sec resolution	1	
7	Switch	Rocker switch	1	
8	Connecting wires	Single strand 0.6 mm Teflon coating	As per requirement	

### IX Precautions to be followed:

1. Do not switch on the power supply unless you have checked the circuit connections as per the circuit diagram.
2. Connect voltmeter and ammeter in correct polarities.
3. Ensure that capacitors are fully discharged before starting the experiment.
4. Use appropriate resistors to control the charging and discharging currents.
5. Safely handle capacitors and avoid overcharging.

### X Procedure:

1. Make the connections as shown in figure 3.3.
2. Reset the stopwatch.
3. Press the switch in the circuit and also stopwatch.
4. Note down the voltage across capacitor C after an equal interval of time of 10 seconds till it reaches maximum charging voltage.

5. Now make the connections as shown in figure 3.4.
6. Reset the stopwatch.
7. Note down the voltage across capacitor C after an equal interval of time of 10 seconds till it discharges fully.
8. Repeat the experiment for the capacitor with different dielectric material and note corresponding readings in the observation table.
9. Plot the charging and discharging curve for two capacitors of different types, taking time on X-AXIS and voltage on Y-AXIS.

## XI Observation table:

**Table 1: Charging and discharging curve of two different capacitors.**

Sr. No.	Time in Seconds	Capacitor 1		Capacitor 2	
		R=	C=	R=	C=
		Charging	Discharging	Charging	Discharging
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

**Calculations:**

1. Time constant ( $\tau$ ) for first set of R and C=\_\_\_\_\_

2. Time constant ( $\tau$ ) for second set of R and C=\_\_\_\_\_

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation**

.....  
.....

**XV Practical related questions**

1. Define dielectric constant?
2. State the meaning of time constant related to charging and discharging of capacitor?
3. List types of capacitors.
4. List the applications of capacitors?

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....





**XVI References/Suggestions for further reading: include websites/links**

1. <https://www.youtube.com/watch?v=bow4rworT-k>
2. [https://www.electronics-tutorials.ws/rc/rc\\_1.html](https://www.electronics-tutorials.ws/rc/rc_1.html)
3. [https://www.electronics-tutorials.ws/rc/rc\\_2.html](https://www.electronics-tutorials.ws/rc/rc_2.html)
4. <https://www.scribd.com/document/195039117/Charging-and-Discharging-of-a-Capacitor>

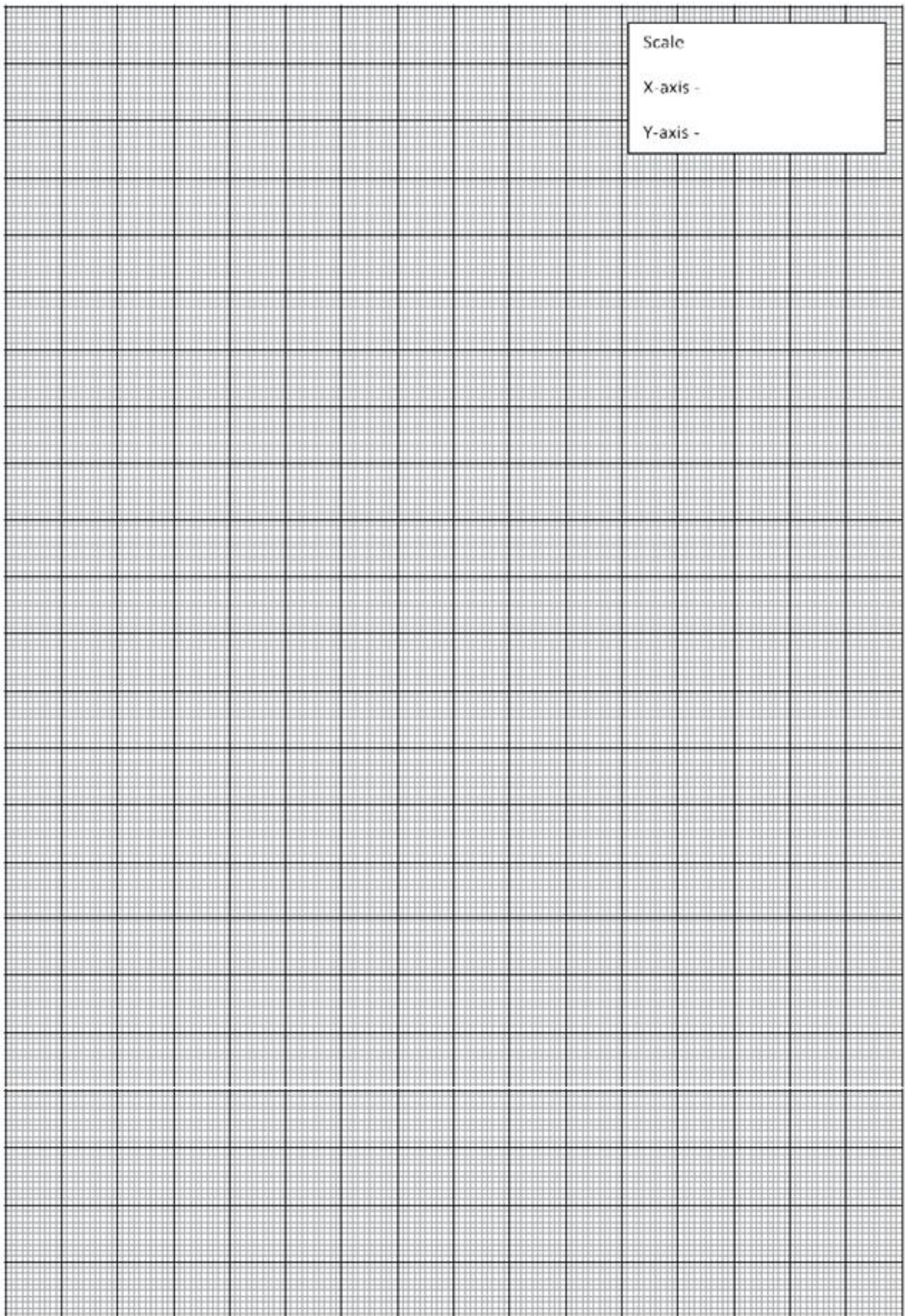
**XVII Assessment Scheme**

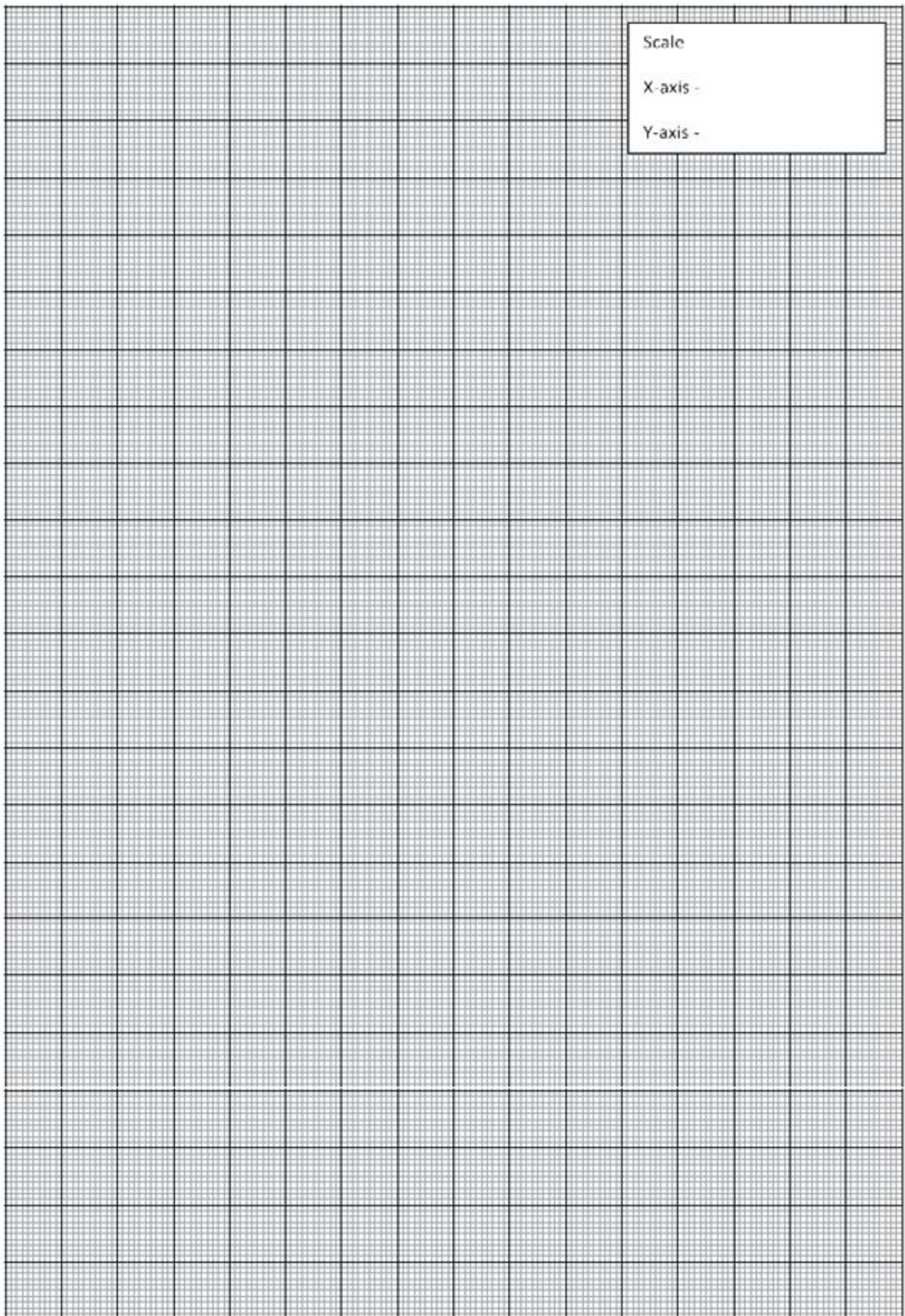
Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	





**Practical No.4: Identification of various electronic components in the given circuit.**

**I Practical significance:**

In industries, to build any hardware, it is necessary to identify electronic components, their terminals, values and packaging. Depending on the application appropriate components need to be selected for better performance. In this experiment students will identify active and passive electronic components on the basis of physical verification and basic knowledge about the components.

**II Industry / Employer Expected outcome(s)**

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Suggest relevant electronic component(s) for the given application.

**IV Laboratory Learning outcome(s)**

Identify various active and passive components in the given circuit.

**V Relevant Affective Domain related outcome(s)**

1. Handle components and instruments with care.
2. Follow all safety precautions.
3. Work in a team.

**VI Relevant Theoretical Background**

An electronic component is any basic discrete electronic device or physical entity part of an electronic system or device. Electronic components are of two types:

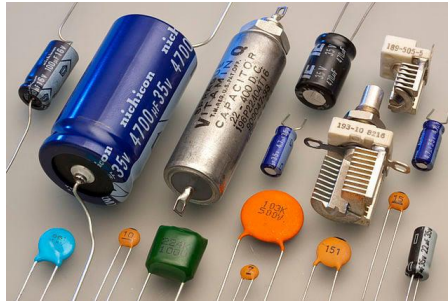
- 1 Passive Components
- 2 Active Components

**Passive components:**

The different passive components are:

**1. Capacitor:**

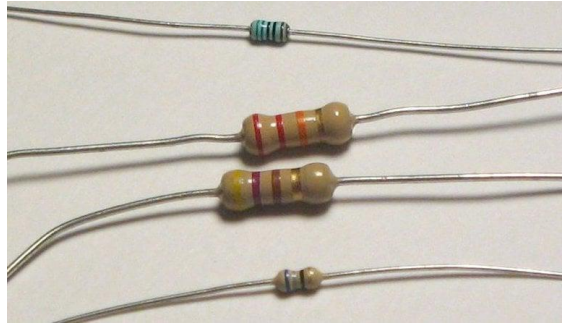
Capacitors are widely used to build different types of electronic circuits. A capacitor is a passive two-terminal electrical component that can store energy in an electric field electrostatically. In simple terms, it works as a small rechargeable battery that stores electricity. However, unlike a battery, it can charge and discharge in the split of a second.



**Figure 4.1: Capacitors**

## 2. Resistor:

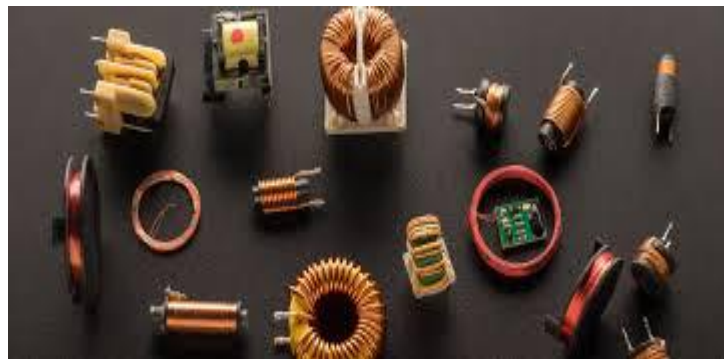
A resistor is a passive two-terminal electrical device that resists the flow of current. It is probably the simplest element in an electronic circuit. It is also one of the most common components as resistance is an inherent element of nearly all electronic circuits. They are usually color-coded.



**Figure 4.2: Resistors**

## 3. Inductor:

An inductor is a passive electronic component that temporarily stores energy in a magnetic field when electric current flows through the inductor's coil. In its simplest form, an inductor consists of two terminals and an insulated wire coil that either loops around air or surrounds a core material that enhances the magnetic field. Inductors help to handle fluctuations in an electric current running through a circuit.



**Figure 4.3: Inductors**

**Active components:**

Different active components are:

**1. Diode**

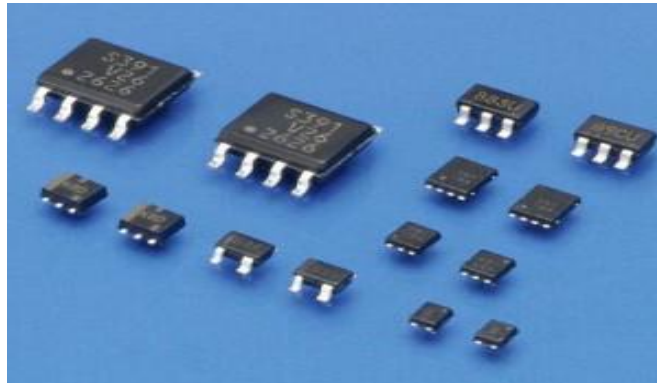
A diode is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction. A PN junction is the simplest form of the semiconductor diode.



**Figure 4.4: Diodes**

**2. Integrated Circuit ( IC )**

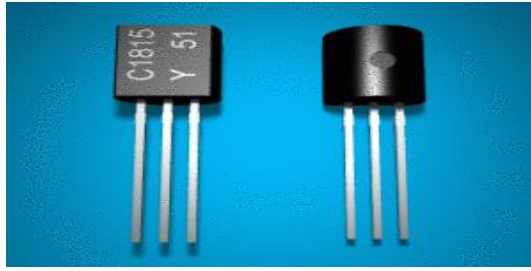
An integrated circuit (IC), commonly called a chip which is made up of a semiconductor material called silicon, in which small electronic components called transistors are formed within the silicon and then wired together with interconnects layered on top of the silicon surface.



**Figure 4.5: Integrated Circuits**

**3. Transistor**

A transistor is a type of semiconductor device that can be used to conduct and insulate electric current or voltage. A transistor basically acts as a switch and an amplifier. In simple words, we can say that a transistor is a miniature device that is used to control or regulate the flow of electronic signals.

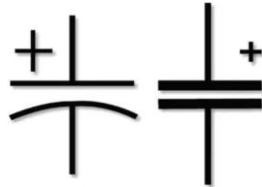


**Figure 4.6: Transistors**

**VII Actual Circuit diagram used in laboratory with equipment specifications.**

**1. Passive Components**

**i. Capacitor**



**Figure 4.7: Capacitor symbol**

**ii. Resistor**



**Figure 4.8: Resistor symbol**

**iii. Inductor**



**Figure 4.9: Inductor symbol**



## 2. Active Components

### i. Diode

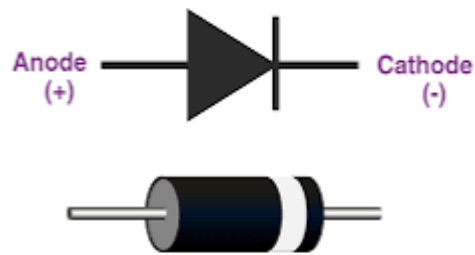


Figure 4.10: Diode symbol

### ii. Integrated Circuit

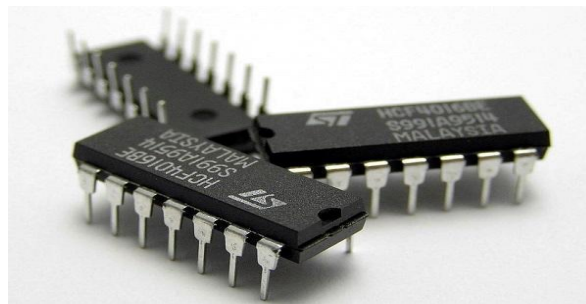


Figure 4.11: Integrated circuit

### iii. Transistor

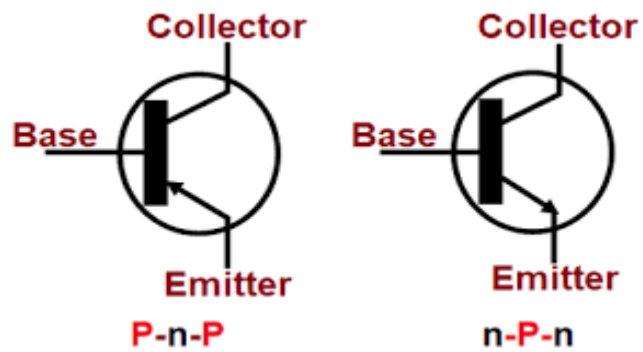


Figure 4.12: Transistor Symbol

**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instrument/Components	Specification	Quantity	Remark
1.	Passive components: i Resistors ii Capacitors iii Inductors iv Potentiometer v Preset	Passive component of any available value	2 each	
2.	Active components : i pn junction diode ii Zener diode iii LED iv Transistor v FET vi UJT	Active component of any available type	2 each	

**IX Precautions to be followed**

1. Ensure that the circuit is powered off before attempting to identify components. This reduces the risk of electric shock and prevents damage to sensitive components.
2. Handle electronic components with care. Avoid bending leads excessively and be gentle when inserting or removing components from the circuit.

**X Procedure:**

1. Begin with passive components like resistors, capacitors, and inductors.
2. Look for symbols representing resistors (usually a zigzag line), capacitors (two parallel lines) and inductors (coils).
3. Identify active components such as transistors, diodes and integrated circuits.
4. Transistors are often represented by three terminals
5. Diodes are represented by a triangle with an arrow pointing out.
6. Integrated circuits (ICs) are usually represented by rectangles with pins extending from the sides.
- 7 Identify the various active and passive components in the given circuit and note down the observations in observation Table 2. Any electronic circuit from the laboratory consisting of active and passive components can be used.

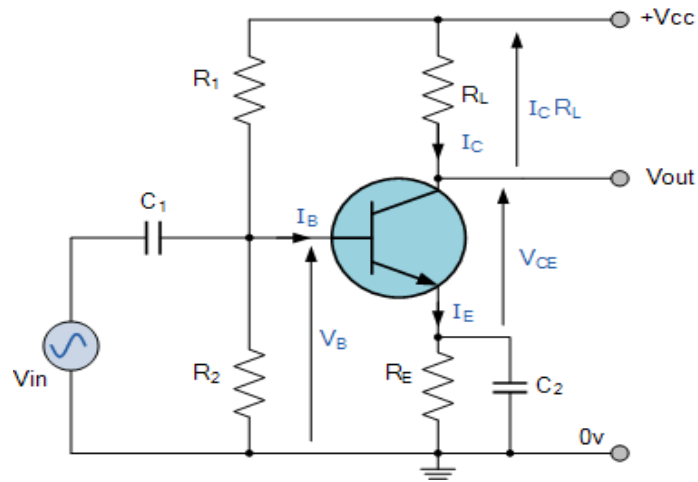


Figure 4.13: Sample circuit-Transistor as an amplifier

**XI Observation table**

**Table 1: Identify Active and passive components**

Name	Symbol	Active or passive Component	Application
Resistor			
Diode			
Transistor			
Inductor			
Electrolytic Capacitor			
LDR			
LED			
FET			

**Draw the circuit used for component identification from the laboratory**

**Table 2: Identify Active and passive components in given circuit**

<b>Sr. No.</b>	<b>Name of Component</b>	<b>Type of component Active / Passive</b>
1		
2		
3		
4		
5		

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....

.....

**XIV Conclusions and recommendation**

.....

.....

**XV Practical related questions**

1. State the procedure to identify the polarity of an electrolytic capacitor.
2. Can you identify the resistance value of a resistor based on its colour bands?
3. State the procedure to identify the anode and cathode of a diode.
4. State the types of transistors and draw the symbols.
5. List any two examples of active and passive components.

**Answers:**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....



**XVI References/Suggestions for further reading: include websites/links**

1. <https://circuitglobe.com/transistor.html>
2. <https://components101.com/articles/electronics-components-and-their-symbols>
3. <https://www.escomponents.com/blog/2019/7/31/active-amp-passive-components-what-is-the-difference-between-the-two>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

**Practical No. 5: LDR as a Dark Sensor****I Practical Significance:**

Light dependent resistors or in other words photo resistors are very useful especially in light /dark sensor circuits. They can also be referred to as photoconductors. Normally the resistance of an LDR is very high, but when they are illuminated with light, resistance drops significantly. Light dependent resistors are a vital component in any electric circuit which is to be turned on and off automatically according to the level of ambient light. For example, solar powered garden lights and night security lighting.

**II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Suggest relevant electronic component(s) for the given application.

**IV Laboratory learning outcome(s)**

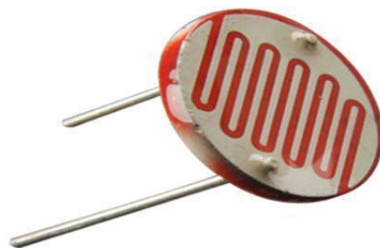
Test the performance of Light Dependent Resistor (LDR) as a dark sensor.

**V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

**VI Relevant Theoretical Background**

An electronic component like LDR or light-dependent resistor is responsive to light. Once light rays drop on it, then immediately the resistance will be changed. The resistance values of LDR in darkness are several mega ohms whereas in bright light it will be dropped to hundred ohms. Thus the resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light. It is often used as a light sensor, light meter, Automatic street light, and in areas where we need to have light sensitivity. LDR is also known as a Light Sensor.



**Figure 5.1: Light dependent resistor**



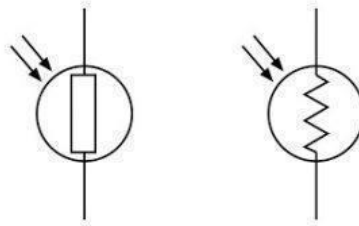


Figure 5.2: LDR (Photoresistor) symbols

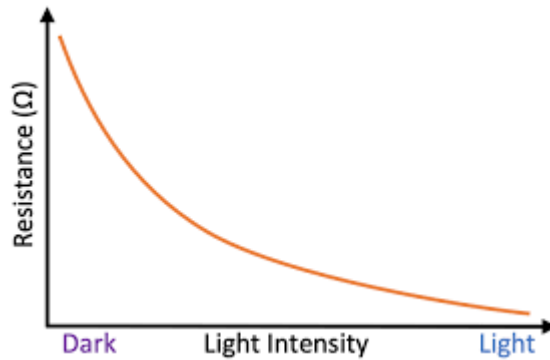


Figure 5.3: LDR characteristics

VII Actual Circuit diagram used in laboratory with equipment specifications.

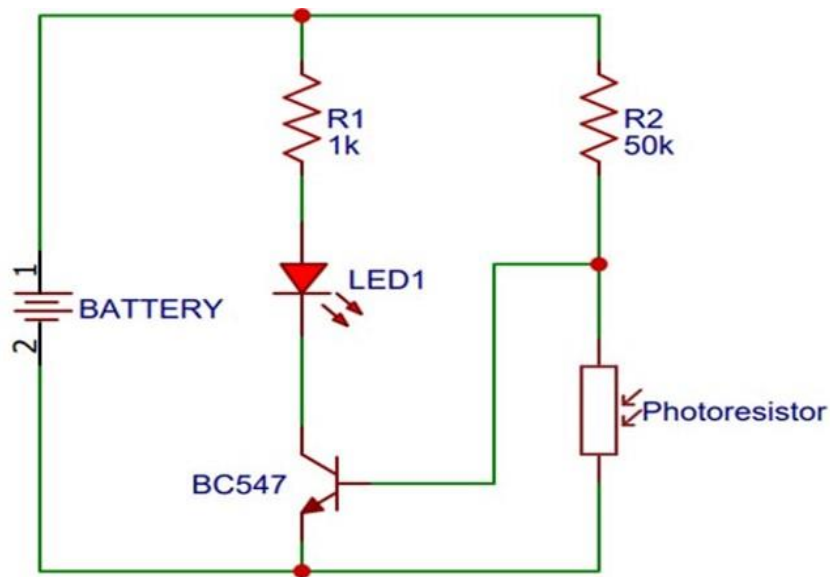


Figure 5.4: Circuit diagram

**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instrument /Components	Specification	Quantity	Remark
1	LDR	450 ohm	1	
2	LED	Red/Yellow/Green color 5mm, 1.8 V to 2.2 V	1	
3	Resistor	1K ohm, 50K ohm	1 each	
4	Transistor- BJT	BC547	1	
5	Breadboard	Size: 16.5 x 5.3 x 0.85 cm.	1	
6	Battery	9 V	1	

**IX Precautions to be followed:**

1. Do not switch on the power supply unless you have checked the circuit connections as per the circuit diagram.
2. No stray light should fall on the LDR.

**X Procedure:**

1. Connect circuit as shown in figure 5.4.
2. Before starting the experiment, ensure that the room is dark or use a dark enclosure to control the light conditions.
3. Note the status of LED under different light conditions.

**XI Observation table:****Table 1: Performance of Light Dependent Resistor (LDR)**

Sr. No.	Light Condition	LED status ON/OFF
1	High (Normal condition)	
2	Low (Dark condition)	

**XII Result(s)**

.....

.....

**XIII Interpretation of results**

.....

.....





**XVI References/Suggestions for further reading: include websites/links**

1. [https://www.electronics-tutorials.ws/io/io\\_4.html](https://www.electronics-tutorials.ws/io/io_4.html)
2. <https://www.instructables.com/Building-a-Simple-Darkness-Detector-Using-LDR/>
3. <https://makeabilitylab.github.io/physcomp/sensors/photoresistors.html>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

**Practical No.6: Reverse Bias Characteristic of Photo-Diode****I Practical significance**

The practical significance of the reverse bias characteristic of a photodiode lies in its impact on the device's performance and its application in various industries. This knowledge is essential for engineers and researchers working across various industries to develop more efficient and reliable photodetectors for specific requirements. Knowledge of the reverse bias characteristic is crucial in designing circuits around photodiodes. Engineers need to consider these characteristics to ensure stable and reliable operation, especially in applications where the photodiode is part of a larger system.

**II Industry / Employer Expected outcome(s)**

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications

**III Course Level Learning outcome(s)**

Suggest relevant electronic component(s) for the given application.

**IV Laboratory Learning outcome(s)**

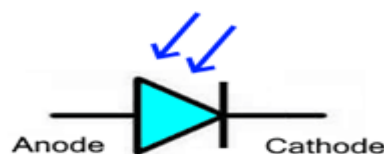
Plot reverse bias characteristic of Photo-diode for different intensity of incident light on it.

**V Relevant Affective Domain related outcome(s)**

- 1 Handle components and equipment carefully.
2. Select instruments of required range.

**VI Relevant Theoretical Background**

A photodiode is a two terminal PN-junction diode that is operated by first reverse biasing the junction and then illuminating it by light energy to produce electric current. It is also called a photo-detector/ light detector/ photo-sensor. These diodes are designed to work in reverse bias condition, it means that the P-side of the photodiode is associated with the negative terminal of the battery and N-side is connected to the positive terminal of the battery. This diode is very sensitive to light so when light falls on the diode it changes light into electric current.

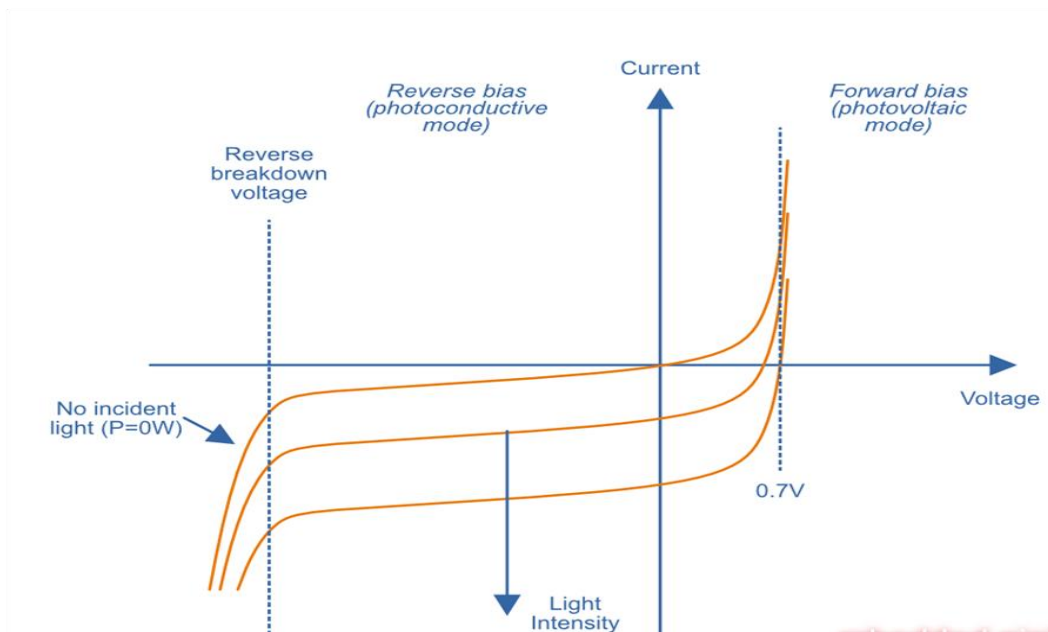


**Figure 6.1: Symbol of Photodiode**



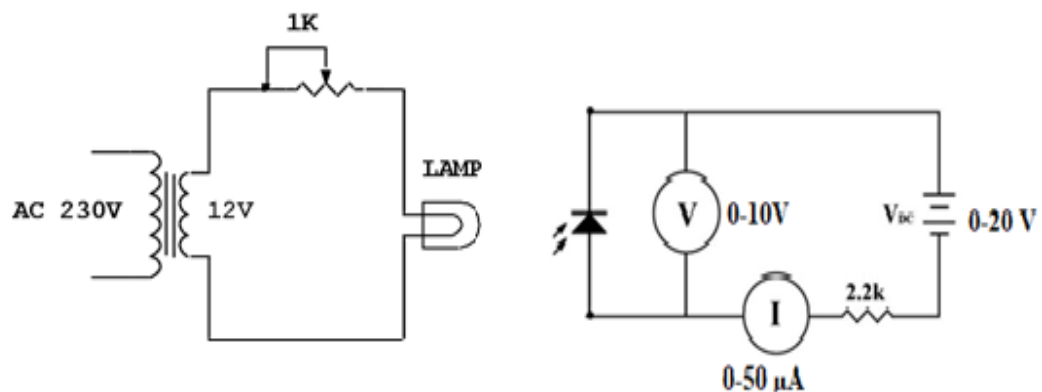
**Figure 6.2: Photo Diode**

**Photo Current ( $I_L$ ):** It is the reverse current produced due to thermally generated electron hole pairs in depletion region due to incident light. Photo current is proportional to light intensity.  
**Dark Current:** A reverse current flows when no light is incident on the device.



**Figure 6.3: Reverse bias characteristics of photodiode**

**VII Actual Circuit diagram used in laboratory with equipment specifications.**



**Figure 6.4: Circuit Diagram**

**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instruments / Components	Suggested Specifications	Quantity	Remark
1.	Experimental kit	840 -1000 contact points: Positive and Negative power rails on opposite side of the board 5.5 CM X 17CM	1	
2.	Photo diode	BPW 34 or any other equivalent photodiode	1	
3.	Connecting wires	Single strand Teflon coating (0.6mm diameter)	As per requirement	
4.	Resistor	2.2K $\Omega$ 0.5Watt	1	
5.	Voltmeter	0-10V	1	
6.	Microammeter	0-50 $\mu$ A	1	
7.	Variable DC Power supply	0-20V, 2A	1	
8.	Lux meter/ Optical power meter	3000 Lumen, Battery-operated hand-held type	1	
9.	Light source.	Portable Lamp mounted on stand	1	

**IX Precautions to be followed**

1. Switch ON the power supply only after checking the circuit connections as per the circuit diagram.
2. Do not exceed the input voltage of the diode beyond the rated voltage of the diode. This may damage the diode.
3. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.

**X Procedure:****I] Test performance of photodiode by varying the light intensity.**

1. Make the connections as per circuit diagram.
2. Apply the reverse voltage and measure the current in absence of light
3. Increase the reverse voltage and light intensity in step and note down the photo current.
4. Change the light intensity and repeat the steps.
5. Plot the graph of reverse voltage (negative X-Axis) versus reverse photo current (negative Y-Axis) for various light intensity.



**II] Test performance of photodiode by varying the distance of the light source.**

1. Make the connections as per circuit diagram.
2. Apply the reverse voltage and measure the current when light is not incident.
3. Keep the input voltage constant at which we get sufficient light intensity and vary the distance of the light source from the photodiode in step and note down the photocurrent.
4. Plot the graph of reverse voltage (negative X-Axis) versus reverse photo current (negative Y-Axis) for different distances.

**XI Observation table****Table 1: Measurement of Photodiode current when light intensity is varied**

Light Intensity ----->	No light Condition ( Lux meter reading- )		Low Light Condition ( Lux meter reading- )		High Light condition ( Lux meter reading- )	
	Sr. No.	V <sub>R</sub> Volts	I <sub>p</sub> (μA)	V <sub>R</sub> Volts	I <sub>p</sub> (μA)	V <sub>R</sub> Volts
	1	2				
	2	4				
	3	6				
	4	8				
	5	10				

**Table 2: Measurement of Photodiode current when distance is varied**

Light Intensity ----->	Position I No light condition ( Distance of light source in cm- )		Position II ( Distance of light source in cm- )		Position III ( Distance of light source in cm- )	
	Sr. No.	V <sub>R</sub> Volts	I <sub>p</sub> (μA)	V <sub>R</sub> Volts	I <sub>p</sub> (μA)	V <sub>R</sub> Volts
	1	2				
	2	4				
	3	6				
	4	8				
	5	10				

**XII Result(s)**

.....

.....

**XIII Interpretation of results**

.....

.....

**XIV Conclusions and recommendation**

.....

.....

**XV Practical related questions**

1. Define dark current in a photodiode.
2. State the applications of photodiodes.
3. Name any two photodiode materials.
4. State two advantages of photodiodes.

**Answers:**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....



**XVI References/Suggestions for further reading: include websites/links**

1. <https://www.electronicshub.org/photodiode-working-characteristics-applications/>
2. <https://www.electronicshub.org/photodiode-working-characteristics-applications/>
3. <https://www.youtube.com/watch?v=GdJnJiQZkqE>
4. [https://www.eecis.udel.edu/~goossen/Course PE/lab/lab6.PDF](https://www.eecis.udel.edu/~goossen/Course_PE/lab/lab6.PDF)
5. [https://www.ece.rice.edu/~jdw/243\\_lab/exp2.3.html](https://www.ece.rice.edu/~jdw/243_lab/exp2.3.html)

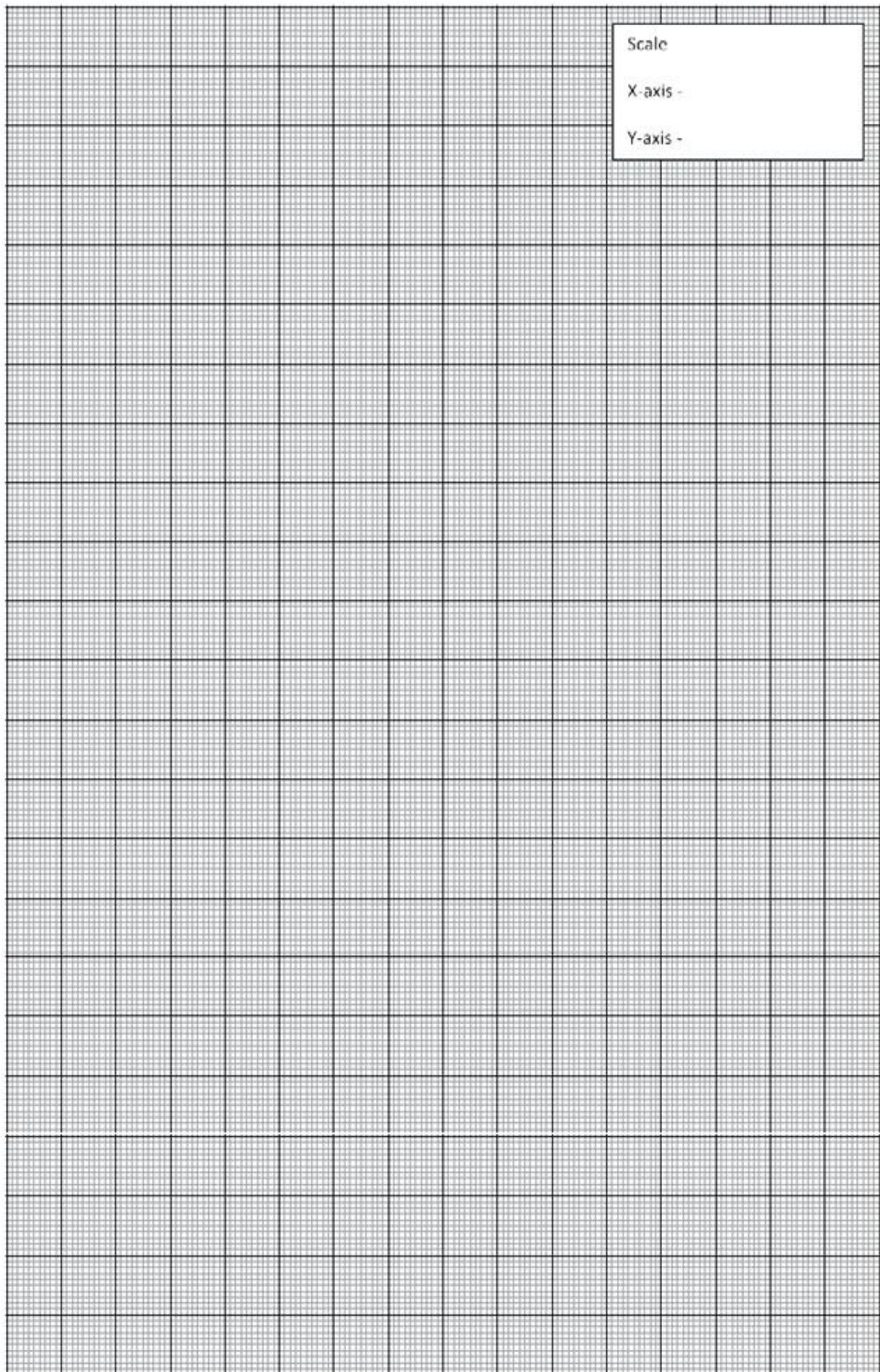
**XVII Assessment Scheme**

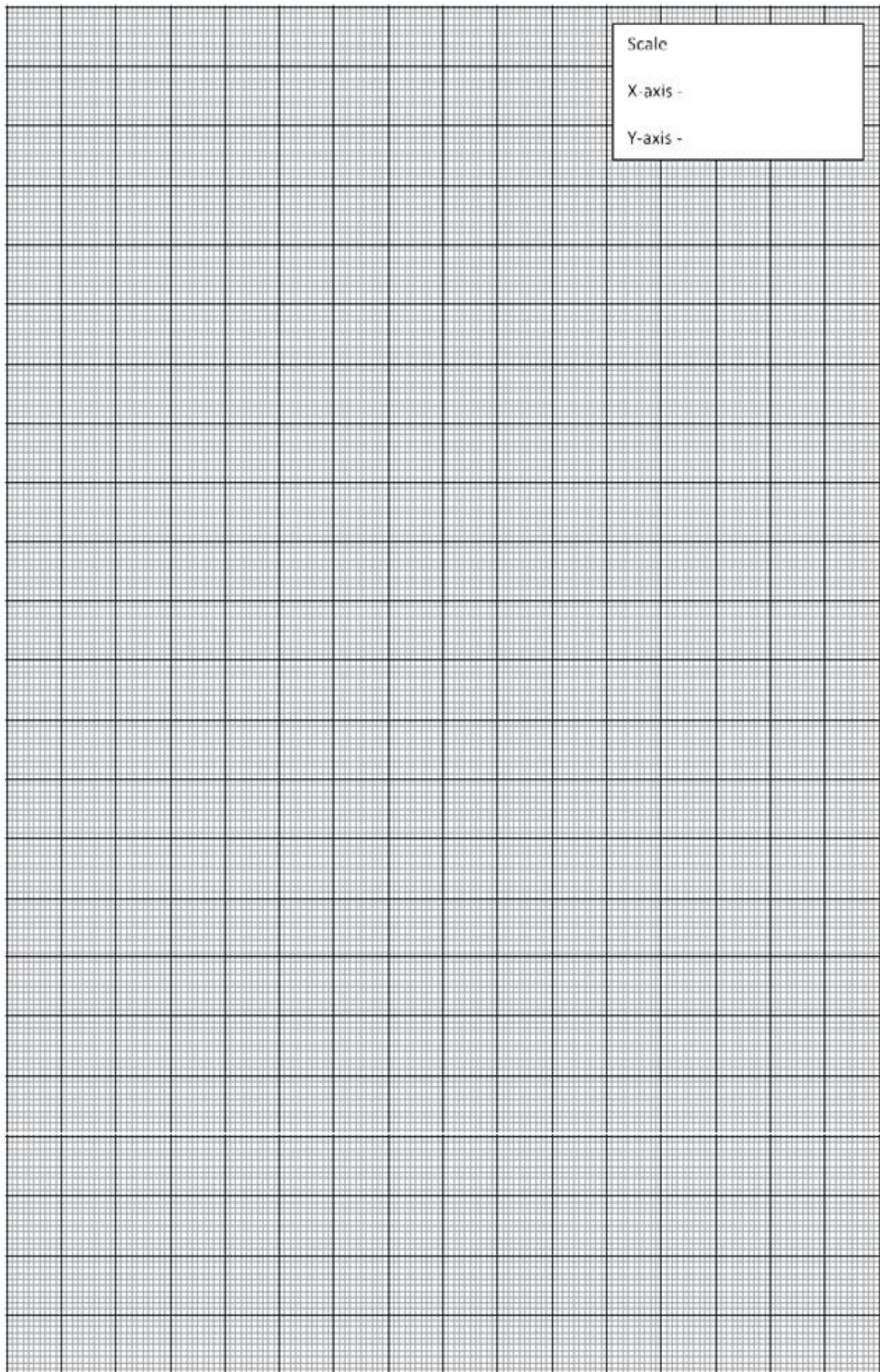
Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	





## Practical No.7: Testing of different IC

### I Practical Significance

Testing integrated circuits (ICs) is crucial for ensuring the proper functioning of electronic devices. Faulty ICs can lead to malfunction, incorrect outputs or even damage to other components. Testing helps to identify and eliminate these issues before they cause problems in real world applications.

### II Industry / Employer Expected outcome(s)

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

### III Course Level Learning outcome(s)

Suggest relevant electronic component(s) for the given application.

### IV Laboratory Learning outcome(s)

Test the identified analog IC's, digital IC's.

### V Relevant Affective Domain related outcome(s)

1. Follow safe practices
2. Handle electronic components and instruments carefully

### VI Relevant Theoretical Background:

**Integrated Circuit-** An integrated circuit, also known as a microchip or IC, is a small electronic device made up of multiple interconnected electronic components such as transistors, resistors, and capacitors fabricated on a single crystal chip of Silicon.

#### Classification of ICs-

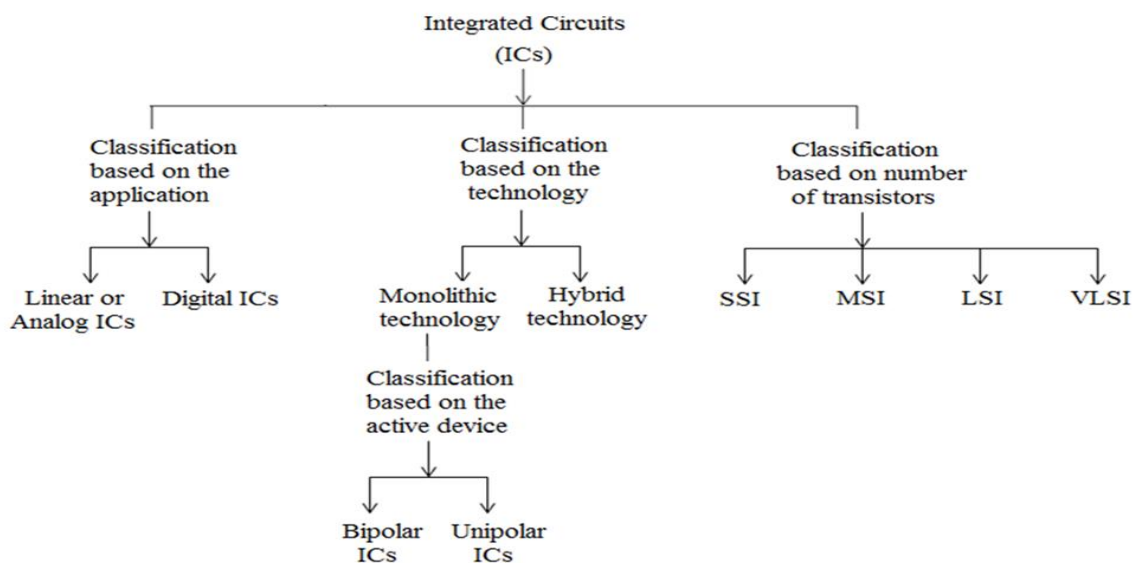


Figure 7.1 Classification of ICs

### **Classification of ICs based on application:**

- A linear IC is one which performs linear operation on the signal like amplification. For example OP-AMP IC.
- Digital ICs involve the combinational and sequential operation on signals. For example, a microprocessor IC.

### **Classification of ICs based on technology:**

- Monolithic IC is built into a single Silicon crystal.  
Thick and Thin film on insulating substrate of glass or ceramic is deposited.
- Hybrid or multi chip IC is formed by interconnecting a number of individual chips or by recombination of monolithic and film IC technology.

### **Classification of ICs based on number of components:**

ICs are classified depending upon the number of components integrated on the same chip.

- Small Scale Integration (SSI)-1 to 10 components
- Medium Scale Integration (MSI)- 10 to 500 components
- Large Scale Integration(LSI)- 500 to 20,000 components
- Very Large Scale Integration (VLSI)-20,000 to 10,00,000 components

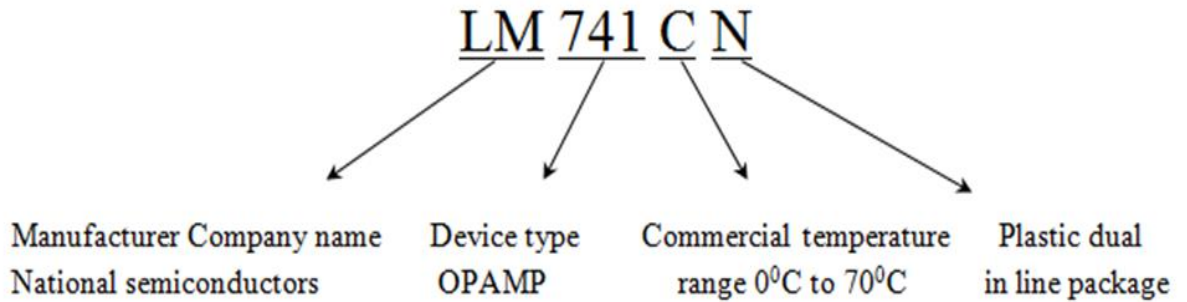
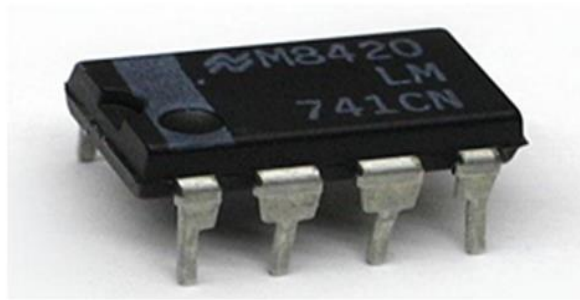
### **Identification of IC-**

ICs can be identified by certain numbers and alphabets printed on them. IC Alphanumeric code signifies Manufacturing Company name, Logic family, Temperature range, Logic subfamily, Device type and Package type.

1. Manufacturing Company name: Prefix is the first part of the nomenclature of IC. It consists of two or three alphabets. Prefix indicates name of manufacturer. For example SN is used for Texas instruments, HEF for Philips, DM for National semiconductors and  $\mu$ A for Fairchild.
2. Logic family: This code consists of two numbers. 74 signifies TTL logic family with commercial temperature range  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  , 54 signifies military temperature range  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
3. Logic series: This code signifies logic subfamily. For example L is Low Power TTL and LS is Low power Schottky
4. Device type: This indicates device function/type, For example 04 is for hex inverter, and 08 is for quad two input AND gate.
5. Package type: It signifies the package type of IC for example, N is for plastic dual in line and J is for ceramic dual in line package.



Figure 7.2 shows IC 741, which is a linear or analog IC and its identification.



**Figure 7.2 IC 741 Identification**

If 741 is the IC which is manufactured by different manufacturers, manufacturers add their own designation as shown below.

**Table 1 -IC 741 manufacturers with designation**

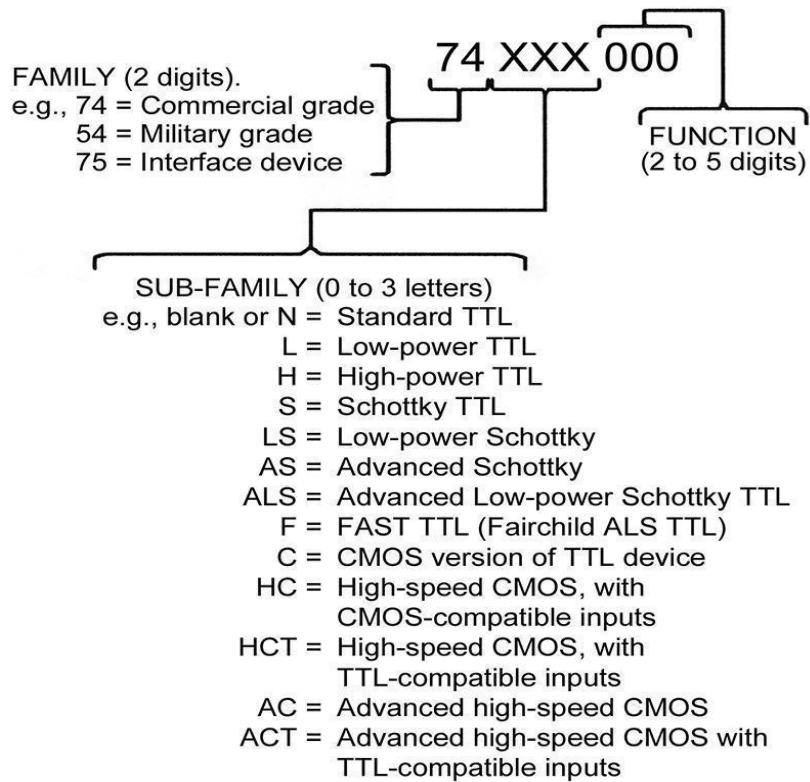
<b>Manufacturers</b>	<b>Designation</b>
National Semiconductor	LM741
Motorola	MC1741
RCA	CA741
Texas Instrument	SN 52741
Fairchild	μA741

741 is a military grade op-amp.

741C is a commercial grade op-amp.

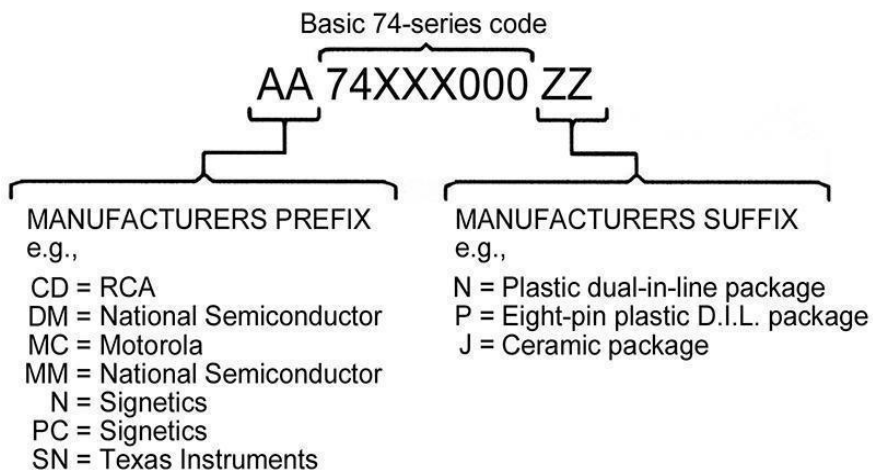
741 A and 741 E are the improved versions of 741 and 741 C.

Figure 7.3 explains the basic 74XX series code numbers. Which is a digital IC series.



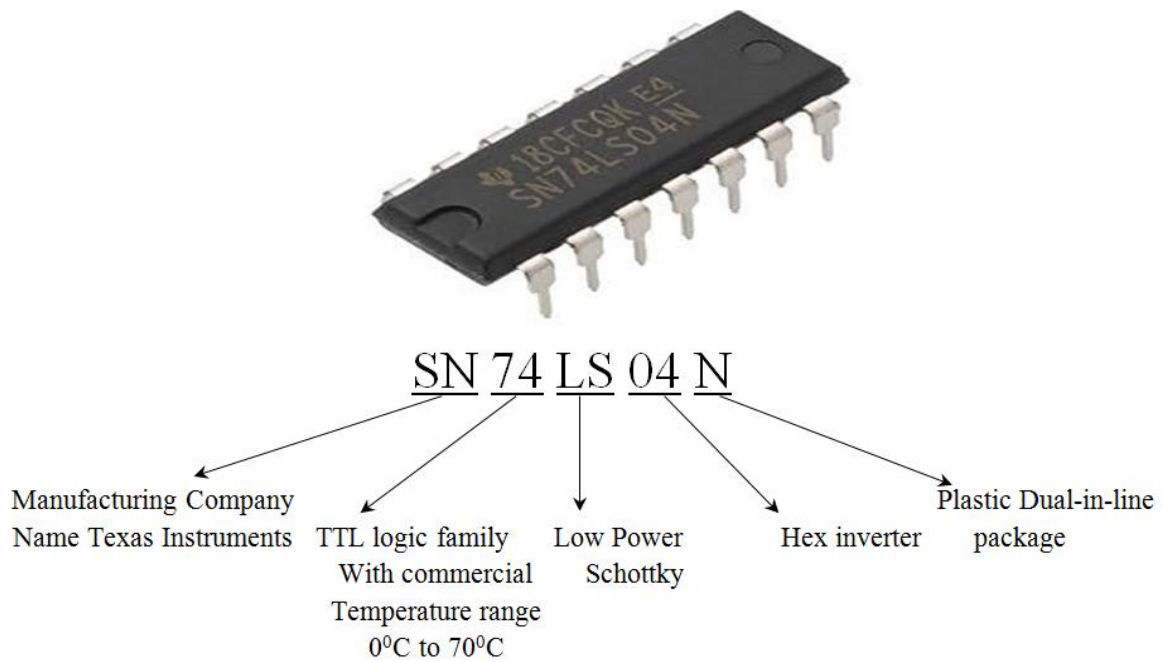
**Figure 7.3 74XX series code numbers**

Figure 7.4 explains the basic 74XX series code elaborated with a manufacturer’s prefix and/or suffix



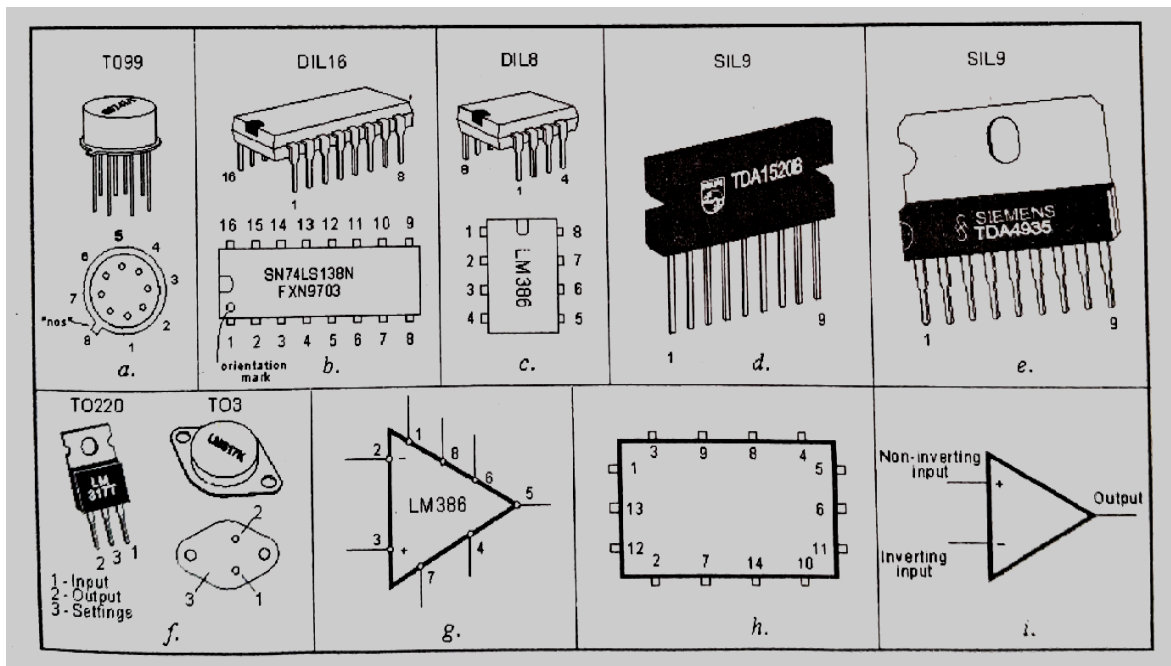
**Figure 7.4 74XX series code elaborated with a manufacturer’s prefix and/or suffix.**

Figure 7.5 shows IC 7404, which is a digital IC and its identification



**Figure 7.5 IC 7404 and its identification**

**IC packages:** ICs may have different packages as flat type, Transistor pack, DIP pack, metal can type. The pins are numbered anti-clockwise around the IC starting near the notch or dot. The diagram shows the numbering for 8-pin and 14-pin ICs, but the principle is the same for all sizes.



**Figure 7.6 IC packages**

**IC tester:** Universal IC tester is used to test analog and digital (TTL, CMOS) ICs. IC tester internally compare the output of an IC (truth table) with a software program which is already in tester and accordingly display testing results of IC as Good or Bad.

## VII. Actual Equipment/ Circuit diagram used in laboratory with equipment specifications:



Figure 7.7 Universal IC Tester

## VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Instrument/ Components	Specification	Quantity	Remark
1	IC tester	Universal IC Tester	1	
2	ICs	Analog and Digital ICs (TTL ICs, CMOS ICs)	8	

## IX Precautions to be followed

1. Care should be taken while handling pins of ICs.

## X Procedure:

1. Switch on the IC tester.
2. Observe test message "HELLO" displayed on screen which is flashing for three times. Then it is followed by the message "IC no -?"
3. If the message "IC no-??" is displayed on the display, it means that the instrument is ready for testing.
4. Insert IC to be tested in TEST socket properly. While inserting IC under test in TEST socket, care should be taken to align bottom edge of IC under test with bottom edge of test socket.
5. Now enter the IC no. using keyboard.
6. Press the test key.

7. If the message "IC GOOD" is displayed alternating with the IC number then it means that the IC under test is good and can be used in circuit.
8. If the message " No ERROR" is displayed, it means that the IC cannot be checked on this IC tester.
9. If the message "IC BAD" is displayed it means that the IC is faulty and cannot be used.

**XI Observation table:**

**Table 1: Testing of ICs**

Sr. No.	Type of IC (Analog / Digital-TTL/CMOS)	IC number	Result (Good/Bad)
1			
2			
3			
4			
5			
6			
7			
8			

**XII Result(s)**

.....  
 .....

**XIII Interpretation of results**

.....  
 .....

**XIV Conclusions and recommendation**

.....  
.....

**XV Practical related questions**

1. List analog and Digital IC numbers with their function (2 of each).
2. List advantages of ICs.
3. List applications of ICs.
4. State factors taken into account while selecting the type of package for a particular application.

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

**XVI References/Suggestions for further reading: include websites/links**

1. [https://en.wikipedia.org/wiki/Integrated\\_circuit](https://en.wikipedia.org/wiki/Integrated_circuit)
2. [https://onlinecourses.nptel.ac.in/noc24\\_ee73/preview](https://onlinecourses.nptel.ac.in/noc24_ee73/preview)

**XVII Assessment Scheme**

<b>Performance indicators</b>		<b>Weightage</b>
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

<b>Marks Obtained</b>			<b>Dated Sign of Teacher</b>
<b>Process Related(15)</b>	<b>Product Related(10)</b>	<b>Total (25)</b>	



**Practical No.8: Determination of SMD component value****I Practical significance:**

Accurate identification of SMD component values is essential in circuit design. Engineers and technicians often work with SMD components in compact electronic devices. In the field of electronics repair and maintenance, technicians frequently encounter SMD components. Being able to determine the values of resistors, capacitors and inductors through their nomenclature is essential for effective troubleshooting and replacement in faulty devices.

**II Industry / Employer Expected outcome(s)**

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Material and Components for relevant electronic applications

**III Course Level Learning outcome(s)**

Identify the Surface Mount Devices for specific applications.

**IV Laboratory Learning outcome(s)**

Determine SMD component value (Resistor, Capacitor and Inductor) using their nomenclature.

**V Relevant Affective Domain related outcome(s)**

1. To handle and measure SMD components accurately.
2. Use the required tools and techniques for measuring SMD components
3. Follow proper safety protocols to prevent accidents and ensure a secure working environment during the practical.

**VI Relevant Theoretical Background**

A surface-mount device or SMD is an electronic device for which the components are mounted or placed directly onto the surface of the PCB. Surface-mount technology, or SMT, is the name of the method used for producing an SMD. In the industry it has largely replaced the through-hole technology construction method of fitting components with wire leads into holes in the circuit board. An SMT component is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all.

**● SMD Resistor**

Surface-mount resistors are typically small and rectangular in design, and they are black in colour. On the other side of the terminal is a tiny, gleaming silver terminal with conductive edges. These resistors are designed to be mounted on top of PCBs and soldered to mating landing pads. SMD resistors are available in a variety of sizes, including 0805 (0.8mm long by 0.5mm broad), 0603 and 0402. They're ideal for bulk circuit board manufacture or designs in which space is limited.

SMD resistors are labelled with a three-digit code, with the first two digits representing the resistance value's first two integers and the third digit representing the multiplier, such as x1, x10, x100, and so on. As an example,

$$103 = 10 * 1,000 \text{ ohms} = 10 \text{ k}\Omega \text{ (kilo ohms)}$$

$$392 = 39 * 100 \text{ ohms} = 3.9 \text{ k}\Omega$$

$$563 = 56 * 1,000 \text{ ohms} = 56 \text{ k}\Omega$$

$$105 = 10 * 100,000 \text{ ohms} = 1 \text{ M}\Omega \text{ (Mega ohms)}$$

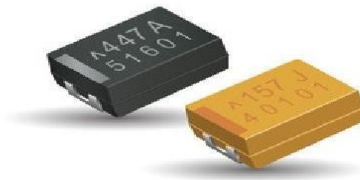
- **SMD Capacitors**

SMD capacitors are PCB parts consisting of two metal pieces separated by an insulator and mainly used to store energy. "C" stands for capacitance, and the unit of capacitance is Farad (F). The unit F is too big for SMDs' capacitance, and we usually use the smaller units  $\mu\text{F}$ , nF, and pF.  $1\mu\text{F}$  equals 1000nF,  $1\text{nF}$  equals 1000pF.

SMD capacitors are classified into different types based on the dielectric material used like the following.

- Multilayer Ceramic Capacitor
- Tantalum Capacitor
- Electrolytic Capacitor

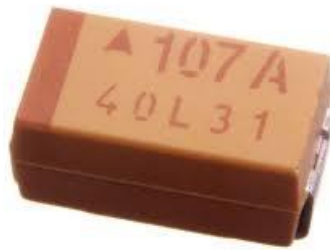
## VII Actual Circuit diagram used in laboratory with equipment specifications.



**Figure 8.1 SMD Resistor**



**Figure 8.2: Ceramic SMD Capacitor**



**Figure 8.3: Tantalum SMD Capacitor**



**Figure 8.4: Electrolytic SMD capacitor**

### VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Instruments /Components	Specifications	Quantity	Remark
1.	Different values of SMD resistor, SMD capacitor and SMD Inductor	SMD component of any available value	3 Each	

### IX Precautions to be followed

1. Handle SMD components with care to prevent damage.

### X Procedure:

1. Identify the SMD Component.
2. Inspect the SMD component for any markings or codes.
3. Use a magnifying glass if necessary.
4. Decode resistor values:
  - For SMD resistors, the codes typically include a three-digit or four-digit number.
  - Decode the digits to determine the resistance value.
  - The first two numbers indicate the absolute numbers of the resistance value, and the last number means the power of 10.
  - For example, if the code is "473," it represents a 47k $\Omega$  resistor.

5. Decode Capacitor Values:

- For SMD capacitors, the codes may include alphanumeric characters.
- In a combination of Arabic numbers and working voltage: the first two numbers indicate the absolute numbers of the capacitance value, and the last number means the power of 10.
- For example, 107 means  $10 \times 10^7 \text{pF}$  ( $= 100\mu\text{F}$ ), 225 means  $22 \times 10^5 \text{pF}$  ( $= 2.2\mu\text{F}$ )

6. Decode Inductor Values:

- SMD inductors often have codes that include numeric values and unit symbols.
- Decode the values to determine the inductance value.
- For example, if the code is "330," it may represent 33  $\mu\text{H}$ .

7. Note down the component name and decoded values.

**XI Observation table**

**Table 1: Determine SMD component value**

Sr. No.	Type of SMD component	Number printed on component	Value of component

**XII Result(s)**

.....

.....



.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

**XVI References/Suggestions for further reading: include websites/links**

1. [https://www.electronics-tutorials.ws/resistor/res\\_1.html](https://www.electronics-tutorials.ws/resistor/res_1.html)
2. <https://www.seedstudio.com/blog/2017/12/28/difference-between-smt-and-smd/>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

**Practical No.9: Soldering of SMD.****I Practical significance:**

SMD (Surface Mount Device) soldering is a method of soldering electronic components directly onto the surface of a printed circuit board (PCB). It involves soldering Tiny components with small solder pads, eliminating the need for drilling holes in the board.

**II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Identify the Surface Mount Devices for specific applications.

**IV Laboratory Learning outcome(s)**

Soldering of Surface Mounted Devices (SMD).

**V Relevant Affective Domain related outcome(s)**

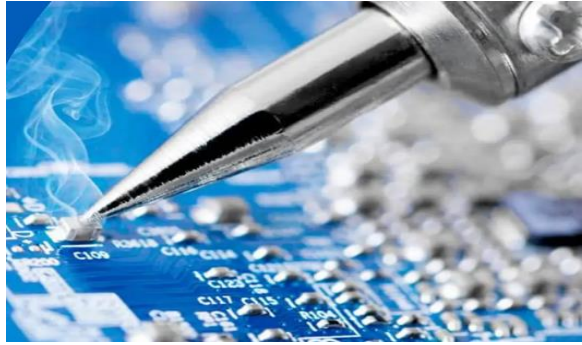
1. Follow safe practices.
2. Handle electronic components and instruments carefully.

**VI Relevant Theoretical Background**

Soldering is a process of joining two metal surfaces together using a filler metal called a solder. The soldering process consists of heating the surfaces to be joined and melting the solder, which is then allowed to cool creating a strong and durable joint. Soldering methods fall into three main categories:

1. Manual soldering
  2. Reflow soldering
  3. Wave soldering.
- Manual soldering is a traditional method of soldering leaded components to a PCB. It is generally used for small production runs, laboratory assembly work, rework/repair. Solder reflow is a critical process in the electronics industry, primarily used to attach surface-mount components to printed circuit boards (PCBs). It involves applying solder paste to specific locations on a PCB, placing the components on the paste, and then heating the assembly in a reflow oven
  - Wave soldering is a bulk soldering process used for the manufacturing of printed circuit boards. The circuit board is passed over a pan of molten solder in which a pump produces an upwelling of solder that looks like a standing wave. As the circuit board makes contact with this wave, the components become soldered to the board. Wave soldering is used for both through-hole printed circuit assemblies and surface mount. For soldering of SMD components, reflow soldering is the most common method.





**Figure 9.1 SMD soldering**

**VII Actual Equipment/ Tools used in laboratory with specifications.**



**Figure 9.2 Soldering station**



**Figure 9.3 Flux cord solder wire**



**Figure 9.4 Surface Mounted Components**



**Figure 9.5 Magnifying glass**

**VIII Required Resources/apparatus/equipment with specifications.**

Sr. No.	Instrument /Components	Specification	Quantity	Remark
1	Soldering iron with soldering station	15, 18 W iron	1	
2	Flux cord solder wire	63/27 flux	1	
3	Surface mounted components	SMD- Resistor, Surface Mount Resistor Networks, Ceramic Capacitors for SMT, etc.	1	
4	Magnifying glass.	Hand-held magnifying glass, diameter-75 mm, focal length-15 cm	1	

**IX Precautions to be followed:**

1. Use the lowest effective soldering iron temperature to avoid damaging sensitive components
2. Keep the soldering tip clean between joints to ensure optimal heat transfer to the joint.
3. Apply just enough solder to form a proper fillet on each joint. Insufficient or excess solder can lead to unreliable connections.
4. Avoid touching or bumping the PCB until all solder joints have cooled and hardened.
5. Work systematically from the centre outwards or from small components to larger ones.

**X Procedure:**

1. Ensure the work area is clean and well-ventilated.
2. Inspect and Clean the PCB with some isopropyl alcohol.
3. After cleaning and drying, inspect it under the microscope. Compare the pads, the vias and the traces, to ensure it matches with the board layout provided to the manufacturer. Also ensure the pads are nicely and firmly on the board, and not lifted.
4. Apply Solder Paste (flux) to PCB pads.
5. Place the components on the designated pads. using tweezers.
6. Check that its orientation is correct, and apply flux to the component pads/leads before placement if needed. Place the component in alignment with the corresponding PCB Pads under the microscope's magnification, taking care to precisely align the component, and realign if necessary.
7. Once the first lead is tacked, solder the remaining leads by working out from the tacked lead, and applying the soldering iron to form a good joint on each lead.
8. When finished soldering all leads, thoroughly inspect each solder joint under magnification to check for any shorts or poor wetting that require rework, reflowing or reheating any questionable joints.
9. After soldering is complete, use iso-propyl alcohol and a brush or cotton swabs to clean away any remaining flux residues.

**XI Observation table:****Table 1: Process-Soldering of Surface Mounted Devices**

Sr. No.	Steps followed in the process of Soldering of Surface Mounted Devices
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

**Draw the flow diagram/flow chart showing the soldering procedure.**

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation:**

.....  
.....

**XV Practical related questions**

1. State the procedure to apply solders paste to a PCB for SMD soldering.
2. Compare SMD soldering with other types of soldering methods.
3. List the steps followed in troubleshooting of the SMD soldering PCB.
4. List the tools used to handle small SMD Components while soldering.

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....



**XVI References/Suggestions for further reading: include websites/links**

1. <https://www.electronicclinic.com/smd-soldering-tutorial-for-beginners-tips-tricks-smd-rework-station/>
2. <https://community.element14.com/challenges-projects/project14/circuitprototypetechniques/b/blog/posts/diy-smd-breakout-board-and-soldering-techniques>
3. <https://iowalum.com/what-is-soldering-three-types-of-soldering-methods/>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

**Practical No.10: Identification of given SMD****I Practical significance:**

In industries where electronic devices are manufactured, identifying SMD components accurately is crucial for quality control. Even a small mistake in identifying or placing components can lead to malfunctioning or failure of the electronic device. Understanding SMD components and their characteristics enables students to innovate and design efficient electronic circuits

**II Industry / Employer Expected outcome(s)**

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Material and Components for relevant electronic applications

**III Course Level Learning outcome(s)**

Identify the Surface Mount Devices for specific applications.

**IV Laboratory Learning outcome(s)**

Identify given SMD according to package type.

**V Relevant Affective Domain related outcome(s)**

1. To handle and measure SMD components accurately.
2. Use the required tools and techniques for identifying SMD components

**VI Relevant Theoretical Background**

A surface-mount device or SMD is an electronic device for which the components are mounted or placed directly onto the surface of the PCB. Surface-mount technology, or SMT, is the name of the method used for producing an SMD. There are various types of SMD packages used for different electronic components. Some common package types include:

**Transistor SOT-23 Package:**

- SOT-23 is a small outline transistor package with three leads. It is commonly used for small signal transistors, diodes, and voltage regulators.
- Identification: SOT-23 transistors are typically marked with alphanumeric codes denoting their part number and possibly other information. The pin configuration is available in datasheets, with one lead serving as the collector, one as the emitter, and one as the base.

**Transistor SOT-89 Package:**

- SOT-89 is a surface-mount transistor package with three leads. It's often used for medium-power transistors and voltage regulators.
- Identification: SOT-89 transistors are also marked with alphanumeric codes for part number and other information. The pin configuration varies depending on the specific

component but is typically available in datasheets. It usually has a larger size compared to SOT-23.

### IC SO-8 (Small Outline 8) Package:

- SO-8 is a small outline integrated circuit package with eight leads (pins). It's commonly used for various ICs, including operational amplifiers, voltage regulators and microcontrollers.
- Identification: ICs in SO-8 packages are marked with alphanumeric codes indicating the part number, manufacturer and sometimes additional information like date codes. The pin configuration is standardized with specific pins designated for power supply connections, inputs, outputs, and other functions.

### IC SO-14 (Small Outline 14) Package:

- Description: SO-14 is another small outline integrated circuit package, but with fourteen leads (pins). It's often used for ICs requiring more connections than SO-8, such as certain analog-to-digital converters, operational amplifiers and digital logic ICs.
- Identification: Similar to SO-8 ICs, ICs in SO-14 packages are marked with alphanumeric codes indicating the part number, manufacturer and other relevant information. The pin configuration is also standardized and can be found in datasheets specific to the component.

## VII Actual Circuit diagram used in laboratory with equipment specifications.

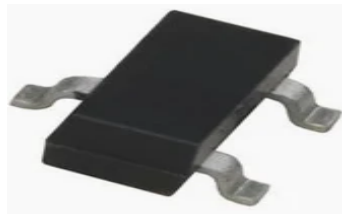


Figure 10.1: Transistor SOT-23 Package



Figure 10.2: Transistor SOT-89 Package

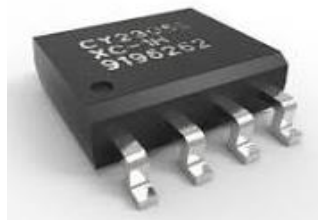


Figure 10.3: IC SO-8 Package



Figure 10.4: IC SO-14 Package



**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instrument /Components	Suggested Specifications	Quantity	Remark
1.	SMD of different packages like transistor SOT23 pack, transistor SOT89 Pack, IC SO8 Pack, IC SO14 pack.	SMD components of suitable specification	3 Each	

**IX Precautions to be followed**

1. Handle SMD components with care to prevent damage.
2. Use tweezers or a vacuum pen to handle SMD components carefully and avoid static discharge.

**X Procedure:**

1. Observe the given SMD Component.
2. Carefully examine the SMD component under good lighting conditions. Use magnifying glass if required
3. Measure the length, width, and height of the component in millimetres (mm).
4. Describe the arrangement of pins on the component (e.g. number of pins, their positions).
5. Note any codes or markings printed on the component.
6. Note the shape, size, and overall appearance of the component.
7. Note down the observations.

**XI Observation table****Table 1: SMD component Identification**

Sr No.	Component	Dimension	No. of Leads	Markings/Codes

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation**

.....  
.....

**XV Practical related questions**

1. Explain the procedure to identify Transistor SOT-80.
2. State the available SMD transistor packages.
3. List any two SMD package dimensions.
4. Explain the importance of proper handling and storage of SMD components.

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

A large area of the page containing 30 horizontal dotted lines, intended for handwritten notes or answers.

**XVI References/Suggestions for further reading: include websites/links**

1. <https://www.hnhcart.com/blogs/learn/different-packages-of-transistors>
2. <https://www.surfacemountprocess.com/smd-component-packages.html>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

### **Practical No.11: Test any small electronic circuit/system**

#### **I Practical Significance:**

Testing circuits is crucial for ensuring the proper functioning of electronic systems. Faulty circuits can lead to malfunction, incorrect outputs, or even damage to other parts of the system. Testing helps to identify and eliminate these issues before they cause problems in real world applications.

#### **II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

#### **III Course Level Learning outcome(s)**

Develop the PCB for the given application.

#### **IV Laboratory Learning outcome(s)**

Test any small electronic circuit/system assembled on general purpose PCB and test it.

#### **V Relevant Affective Domain related outcome(s)**

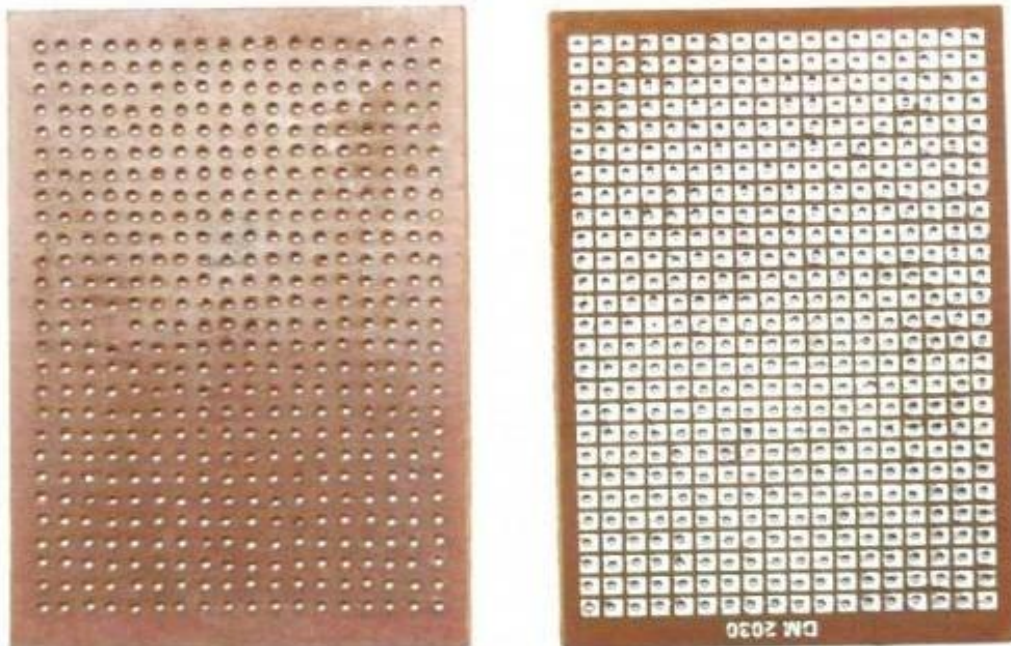
1. Follow safe practices
2. Handle electronic components and instruments carefully.

#### **VI. Relevant Theoretical Background:**

##### **General Purpose PCB:**

Printed Circuit Boards commonly abbreviated as PCB is the base of electronics. The PCB provides support as well as electrically connects various Electronic Components in the circuit. General Purpose PCB or Zero PCB or Dotted PCB are perfect for quick prototyping and can be used by students for projects. These PCB's are also used in Industries for Research and Development and Testing of small circuits.

A general purpose PCB is a board that has a grid of holes and pads that can be used to connect various components without a specific layout. You can use wires, jumpers or solder to make the connections.



**Figure 11.1 General purpose PCB**

**Advantages of using General Purpose PCB**

- Low cost.
- Perfect for Prototyping and testing small circuits.
- Short Design Time
- Circuit can be changed at any time

**Disadvantages of using General Purpose PCB**

- Cannot be used for Mass Production.
- Difficult to Repair or Troubleshoot.
- Soldering skills required.
- Difficult to use for complex circuits.

**Soldering:**

Soldering is a process of joining two metal surfaces together using a filler metal called solder. The soldering process involves heating the surfaces to be joined and melting the solder, which is then allowed to cool and solidify, creating a strong and durable joint. Figure 11.2 indicates soldering material required.



Figure 11.2 Soldering material required

Electronic soldering connects electrical wiring to devices and electronic components to printed circuit boards. Electronic connections may be hand-soldered with a soldering iron. Figure 11.3 explains the soldering process.

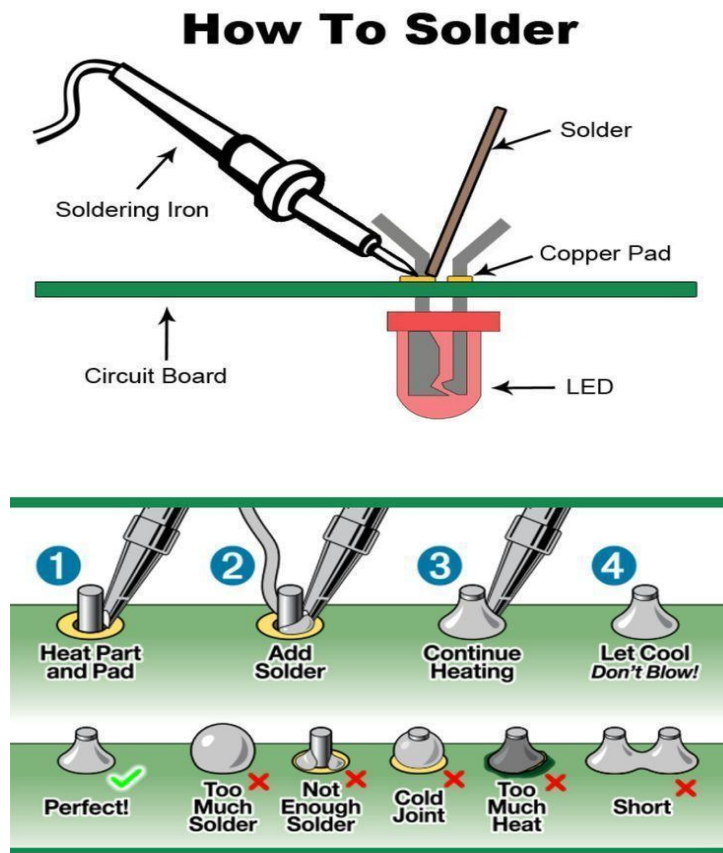


Figure 11.3 Soldering Process

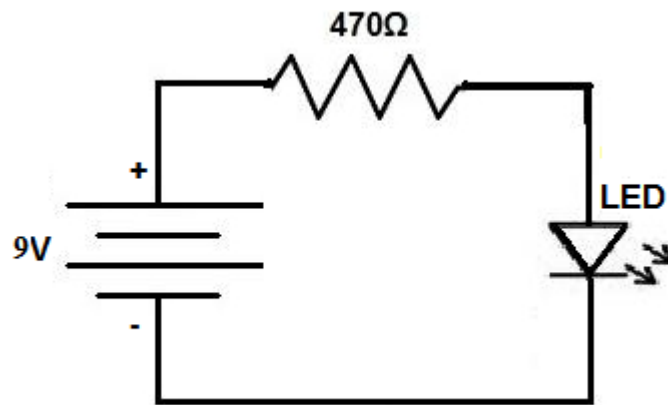
**VII Actual Circuit diagram used in laboratory with equipment specifications:**

Figure 11.4 LED Circuit diagram

**VIII Required Resources/apparatus/equipment with specifications**

Sr. No.	Instrument/ Components	Specification	Quantity	Remark
1	General purpose PCB	(5 X 7 cm) or Available size	1	
2	Soldering iron	25W	1	
3	Soldering flux	Brown Rosin- Rich paste	As per requirement	
4	Soldering material	60/40 Tin/Lead alloy	As per requirement	
5	Battery	9V	1	
6	LED	5mm diffused lens (Red)	2	
7	Resistor	470 Ω	1	
8	Connecting Wires	Single strand Teflon Coating (0.6 mm diameter)	As per requirement	
9	Multimeter	Digital multimeter with continuity testing probes	1	

**IX Precautions to be followed**

1. Handle the soldering iron safely
2. Avoid touching heated components and solder joints with bare fingers
3. Be cautious when soldering near heat-sensitive components such as plastic connectors and ICs



**X Procedure:**

**1. Assemble LED Circuit on General Purpose PCB using following steps of soldering**

**a) Set Up Your Space:**

Before you start, get a clean and organized workspace. Arrange your tools—soldering iron, solder wire, flux, and stand. Good ventilation is crucial to clear fumes produced during soldering.

**b) Check Your Components:**

Examine what you're soldering. Look for damage, proper orientation and correct positioning on the board. This step prevents errors during soldering.

**c) Choose Your Tools:**

Pick the right soldering iron tip based on component size. Use a fine tip for small parts and a broader one for larger ones. Choose quality solder with the right flux for a clean, reliable joint.

**d) Heat Up the Iron:**

Let the soldering iron reach its operating temperature, which usually takes a few minutes. A well-heated iron ensures efficient heat transfer for effective soldering.

**e) Apply Flux:**

Add a bit of flux to the joint area. Flux enhances solder wetting and creates a strong connection. It also reduces oxidation, improving the soldering process.

**f) Tin the Iron Tip:**

Coat the iron tip with a thin layer of solder. This tinning process boosts heat transfer and aids soldering. Wipe off excess solder on a damp sponge to keep the tip clean.

**g) Heat the Joint:**

Place the iron tip on the joint, heating both the component lead and the board pad. Heat the components evenly for smooth solder flow.

**h) Apply Solder:**

Introduce solder to the joint, allowing it to melt and form a smooth connection. Avoid excess solder, as it can cause issues. A steady hand is crucial during this step.

**i) Inspect the Joint:**

After soldering, visually inspect the joint. A well-soldered joint appears shiny and smooth. Check for irregularities and touch up joints if needed for a reliable connection.

**2. Test LED Circuit on General Purpose PCB by Continuity Testing using Multimeter**

- a) **Set up the Multimeter to the continuity or resistance setting**
- b) **Testing between two points of circuit**-Touch probes between the points you want to test for continuity. If using the continuity setting, listen for a beep, If there is continuity (a complete circuit), the multimeter will beep. If using the resistance setting, check the multimeter display. A reading close to zero indicates good continuity.
- c) **Test Traces and Components:** Move the probes along traces, component leads you want to test.
- d) **Identify Open or Short Circuits:** If there is no beep or the resistance is very high, it indicates an open circuit. If there is a constant beep or very low resistance, it suggests a short circuit.

**XI Observation table:**

**Table 1-Circuit Continuity Test**

Sr. No.	Connections of devices in the circuit	Continuity (Yes / No)
1	Battery	
2	LED	
3	Resistor	

**Table 2-Circuit Working Test**

Sr.No.	Battery status	LED (On/Off)
1	Battery connected	
2	Battery not connected	

**XII Result(s)**

.....  
 .....

**XIII Interpretation of results**

.....  
 .....



**XVI References/Suggestions for further reading: include websites/links**

1. <https://www.aixuntech.com/newsinfo/basic-steps-of-hand-soldering-operation/>

**XVII Assessment Scheme**

<b>Performance indicators</b>		<b>Weightage</b>
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

<b>Marks Obtained</b>			<b>Dated Sign of Teacher</b>
<b>Process Related(15)</b>	<b>Product Related(10)</b>	<b>Total (25)</b>	

## **Practical No.12: Use of open source PCB design simulation software and tools**

### **I Practical significance:**

Use of open source PCB design simulation software and tools like eagle, Kicad, PCB, Dip trace, DesignSpark PCB has significant practical importance in modern electronic design. These tools empower designers and engineers to create detailed printed circuit board layouts. Accessibility of open source PCB design simulation software not only reduces cost but also accelerates innovation. Use of open source PCB design software promotes a more inclusive and dynamic environment for electronics development.

### **II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

### **III Course Level Learning outcome(s)**

Develop the PCB for the given application.

### **IV Laboratory Learning outcome(s)**

Use of open source PCB design simulation software and tools like eagle, Kicad, PCB, Dip trace, DesignSpark PCB.

### **V Relevant Affective Domain related outcome(s)**

1. Follow safety practices.
2. Follow ethical practices.

### **VI Relevant Theoretical Background**

PCB design software serves as an electronic mechanism to check the functioning of components assembled within electronic devices. Open source PCB design simulation software and tools like eagle, Kicad, PCB, Dip trace, Designspark PCB can be used.

Use of KiCAD PCB design software is illustrated in this practical.

#### **KiCad Basic Concepts:**

1. KiCad is an open-source software suite for creating electronic circuit schematics, printed circuit boards (PCBs), and associated part descriptions.
2. KiCad supports an integrated design workflow in which a schematic and corresponding PCB are designed together, as well as standalone workflows for special uses.
3. KiCad also includes several utilities to help with circuit and PCB design, including a PCB calculator for determining electrical properties of circuit structures, a Gerber viewer for inspecting manufacturing files, a 3D viewer for visualizing the finished PCB and an integrated SPICE simulator for inspecting circuit behaviour.

4. KiCad runs on all major operating systems and a wide range of computer hardware. It supports PCBs with up to 32 copper layers and is suitable for creating designs of all complexities.

### **KiCad PCB design Workflow:**

The typical workflow in KiCad consists of two main tasks: drawing a schematic and laying out a circuit board.

#### **1. Drawing a schematic:**

The schematic is a symbolic representation of the circuit: which components are used and what connections are made between them. Schematic symbols are pictorial representations of electronic components in a schematic, such as a zigzag or rectangle for a resistor or a triangle for an opamp. The schematic contains symbols for every component in the design, with wires connecting pins in the symbols.

#### **2. Laying out a circuit board:**

Board is the physical realization of the schematic, with component footprints positioned on the board and copper tracks making the connections described in the schematic. Footprints are a set of copper pads that match the pins on a physical component. When the board is manufactured and assembled, the component will be soldered onto its corresponding footprint on the circuit board.

KiCad has a project-based workflow. A KiCad project is a folder with a project file, a schematic, a board layout, and optionally other associated files such as symbol and footprint libraries, simulation data, purchasing information, etc.

### **PCB Design Workflow-**

1. The schematic is drawn first. (Adding symbols to the schematic and drawing the connections between them. Custom symbols may need to be created if appropriate symbols are not already available)
2. At this stage footprints are also selected for each component, with custom footprints created as necessary.
3. When the schematic is complete and the design has passed electrical rules check (ERC), the design information in the schematic is transferred to the board editor and layout begins.
4. The schematic describes which components are in the design and how they are connected; the board editor uses this information to make layout easier and to prevent mismatches between the schematic and PCB. The layout process requires careful placement of each footprint on the circuit board.
5. After component placement, copper tracks are drawn between components based on the connections in the schematic as well as other electrical considerations, such as trace resistance, controlled impedance requirements, crosstalk, etc.
6. Often the schematic will need to be updated after layout has begun; the schematic changes can be easily pulled into the board design.

7. The reverse can often happen: any design changes made in the board layout can be pushed back to the schematic to keep the two consistent.
8. When the board layout is complete and the board has passed the Design Rules Check (DRC), fabrication outputs are generated so that the board can be manufactured by a PCB fabricator.

## VII Actual Circuit diagram used in laboratory with equipment specifications.

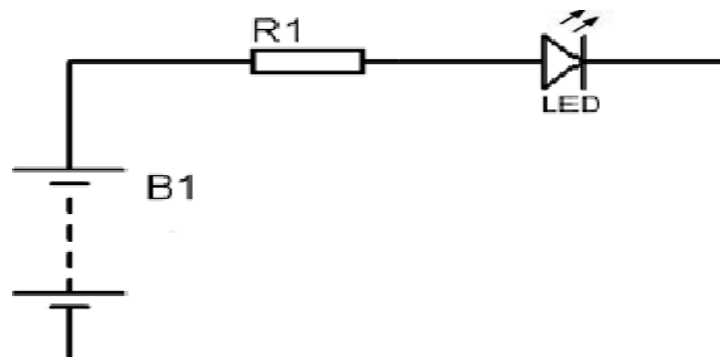


Figure 12.1 Sample circuit diagram

## VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Instrument/Components	Specification	Quantity	Remark
1	Computer System	Any desktop or laptop computer with basic configuration and installed with software with operating system Windows-7 & Windows-10 or 11 (for latest version of KiCad software )	One computer System for each student	
2	KiCad software	Open source- KiCad software version 5.1.4_1 / latest version	-	

## IX Precautions to be followed

1. Handle computer with care.
2. Do not turn off the computer while installation is in progress.

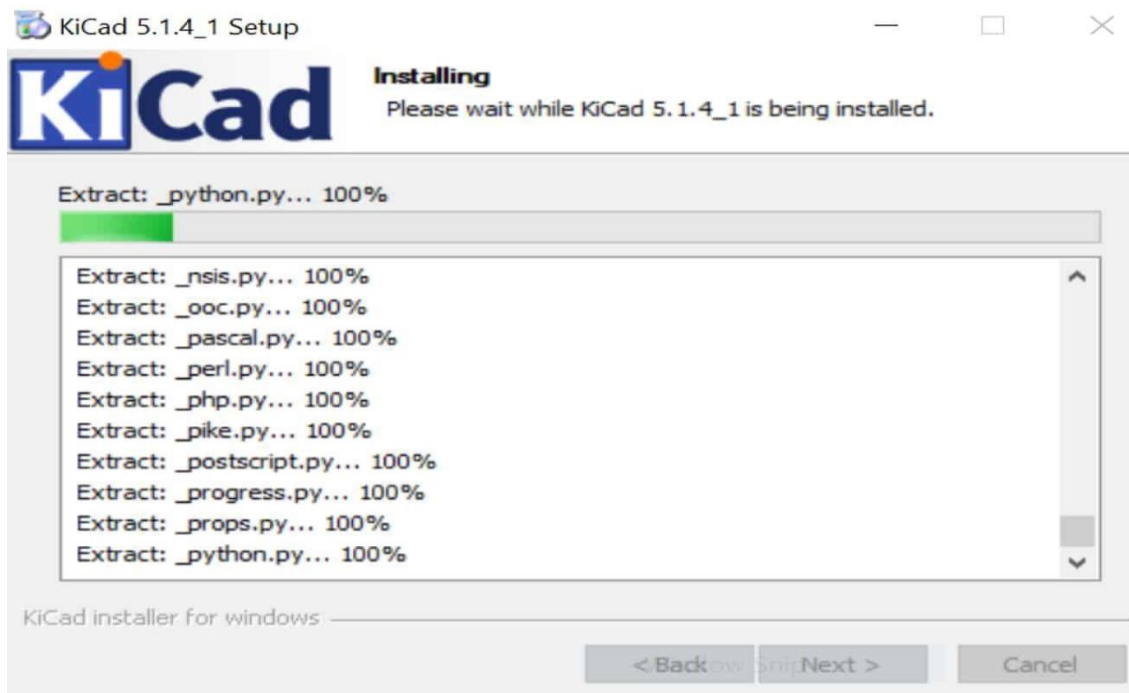
## X Procedure:

### 1. Download and install KiCad

- KiCad is available for Windows, macOS, Ubuntu, and many other platforms. Find the platform alternatives and download the installation files for KiCad here:

<http://kicad.org/download/>



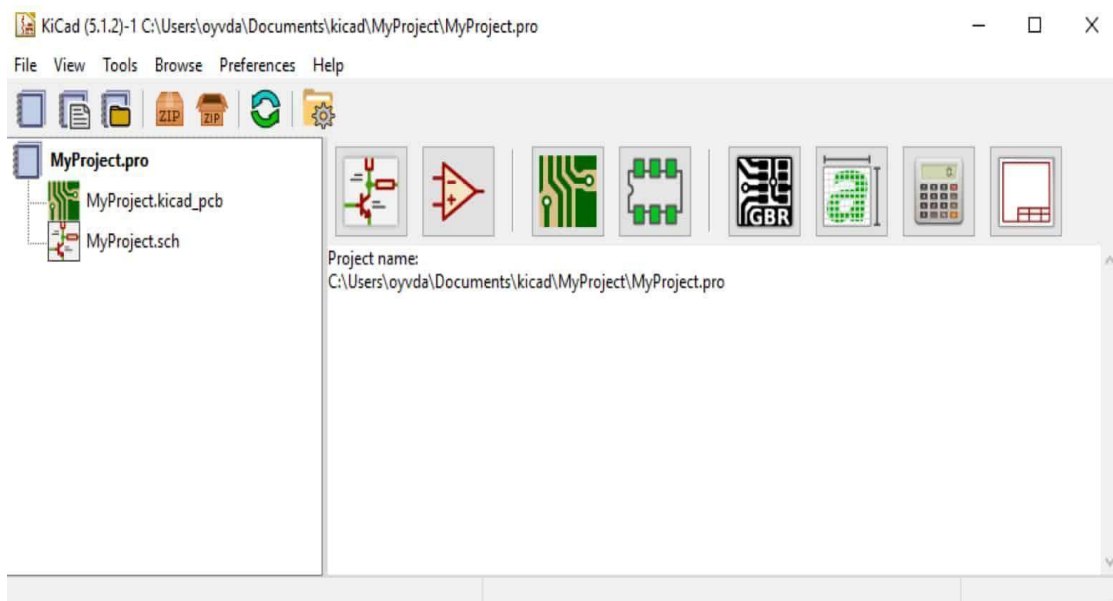


**Figure 12.2 Installing KICAD**

## **PART 1 - DRAWING A SCHEMATIC**

### **2. Starting a New Project**

- When you open up KiCad, you will see the window shown in Figure 12.3. From here, you can open or create new projects.
- To create a new project, click on the File menu and select **New -> Project**.
- Choose where you want to save your project and type in a name for it. Then click on the **Save** button.



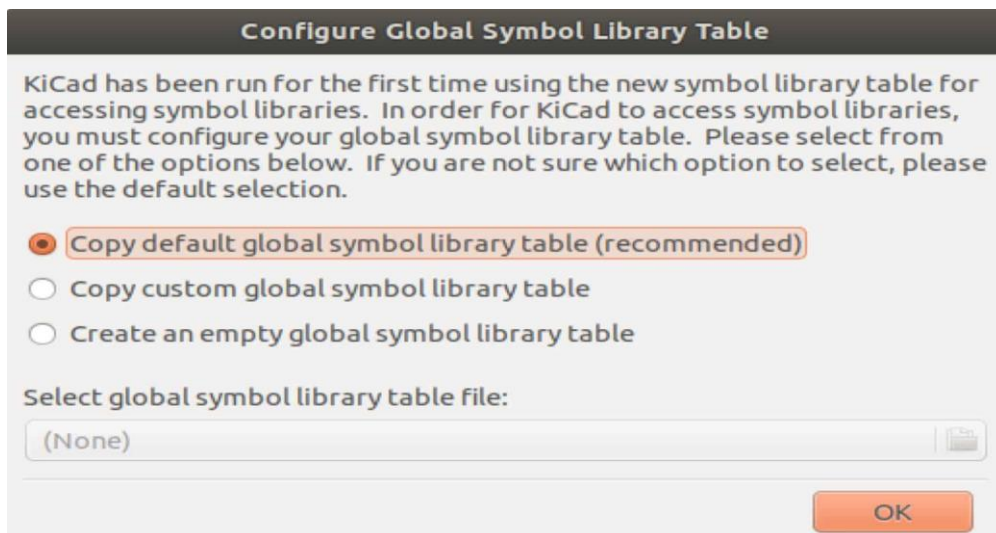
**Figure 12.3 The main KiCad window**

- Your new project will be empty. It is now your job to first create a schematic, then later draw the board layout.
- You create the schematic from the *Schematic Layout Editor*, also called *Eeschema*.
- Open the editor by double-clicking on the schematic file on the left, or by clicking on the Schematic Layout Editor button (Figure 12.4).



**Figure 12.4 Schematic layout editor button**

- When opening the editor for the first time, you might get asked to *Configure the Global Symbol Library Table*.
- Just choose the recommended settings.



**Figure 12.5 Configure global symbol library table**

### 3. Adding Components

- Your schematic is where you draw your circuit. First, you add the components you want. Then you add wires to show how to connect your components.
- To add a component, click on the **Place Symbol** button on the toolbar on the right (or press **A** on your keyboard), then click anywhere in your work area. This brings up the component chooser.



**Figure 12.6 The place symbol button**

- From the component chooser, you can search for the component you want to add. Just type in what you are looking for. For example, if you need a resistor, type in “resistor.” Look through the list of results and choose a good match.

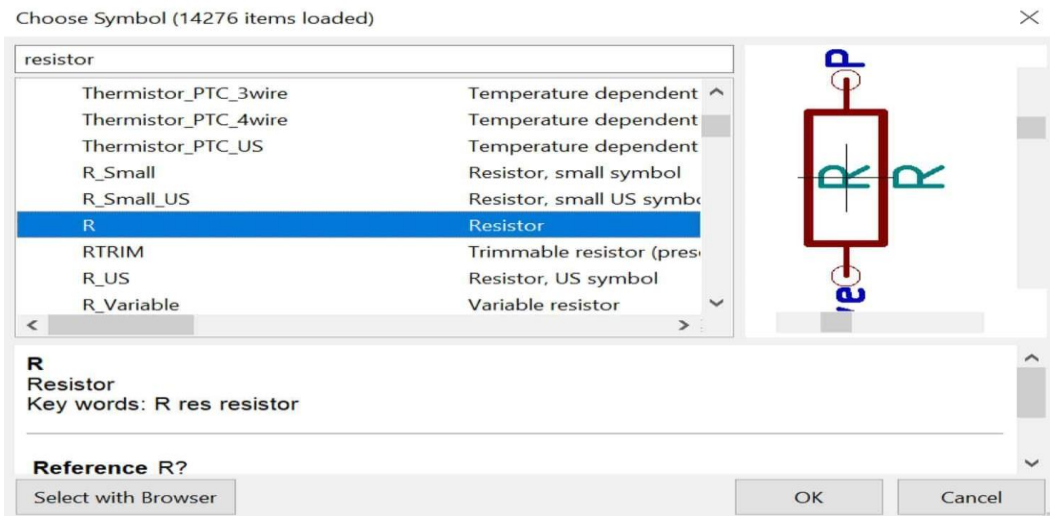


Figure 12.7 The component chooser window

- Place the symbol  
When you have chosen a component, place it in your schematic by clicking in your work area with your mouse.

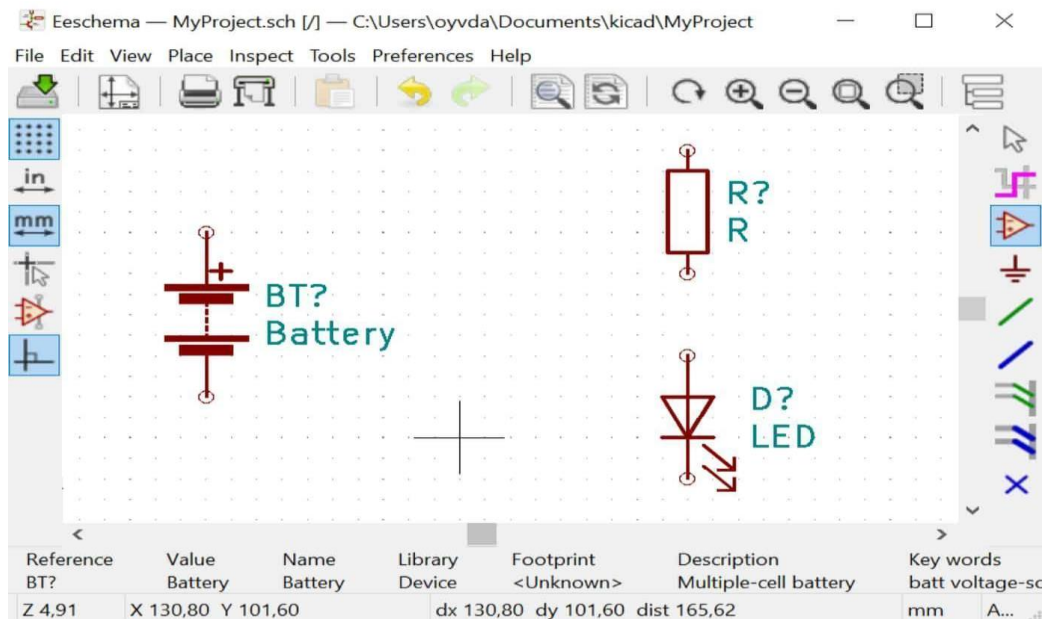
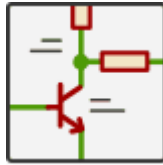


Figure 12.8 A resistor, LED, and battery added to the schematic

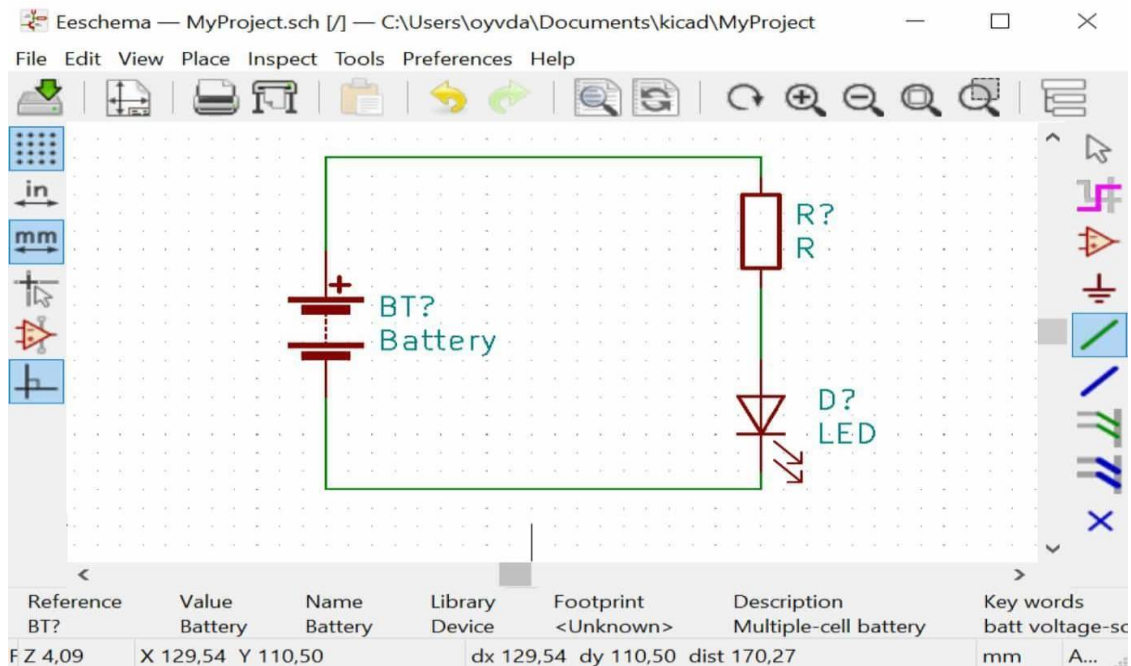
#### 4. Adding Wires

- Now you need to draw wires between the components to connect them. You can do this by clicking on the **Place Wire** button on the toolbar or by pressing **W** on your keyboard.



**Figure 12.9 The Add Wire Button**

- Click on the pin of a component to start drawing a wire. Then click again on the pin where you want the wire to end.

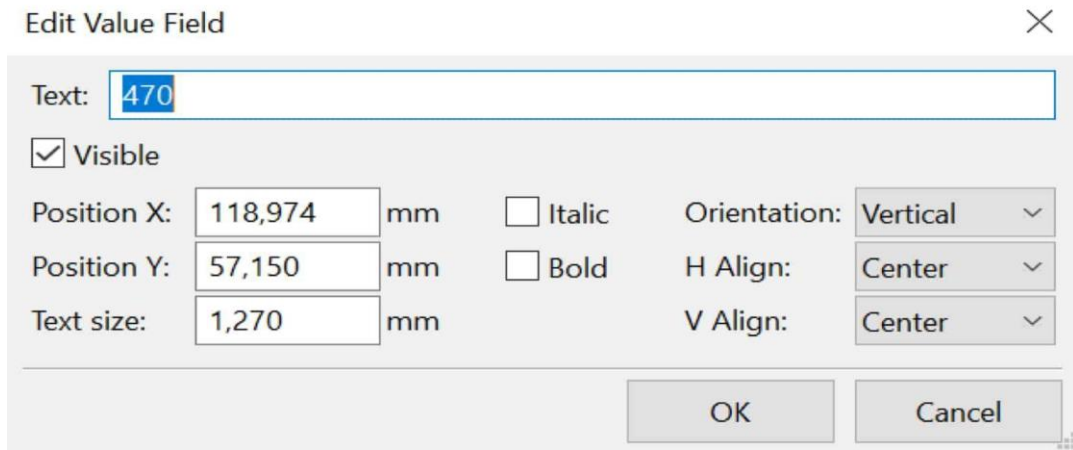


**Figure 12.10 The components with wires connecting them**

- If you want to move a component now that they are connected, you have two options: *Move* and *Drag*
- If you place your mouse pointer over a component and press **M** on your keyboard, you Move the component without the wires. But if you press **G**, you Drag the component with the wires attached.
- If you start moving or dragging a component but then change your mind, just press the **Escape** key on your keyboard to release.

## 5. Adding Symbol Values

- In most cases, a component should have a value. For example, a resistor should have a resistance value. A battery should have a voltage value, etc.
- By pressing **V** on your keyboard, with your mouse pointer over the component, you can edit its value. You also find this option in the menu when right-clicking on the component.

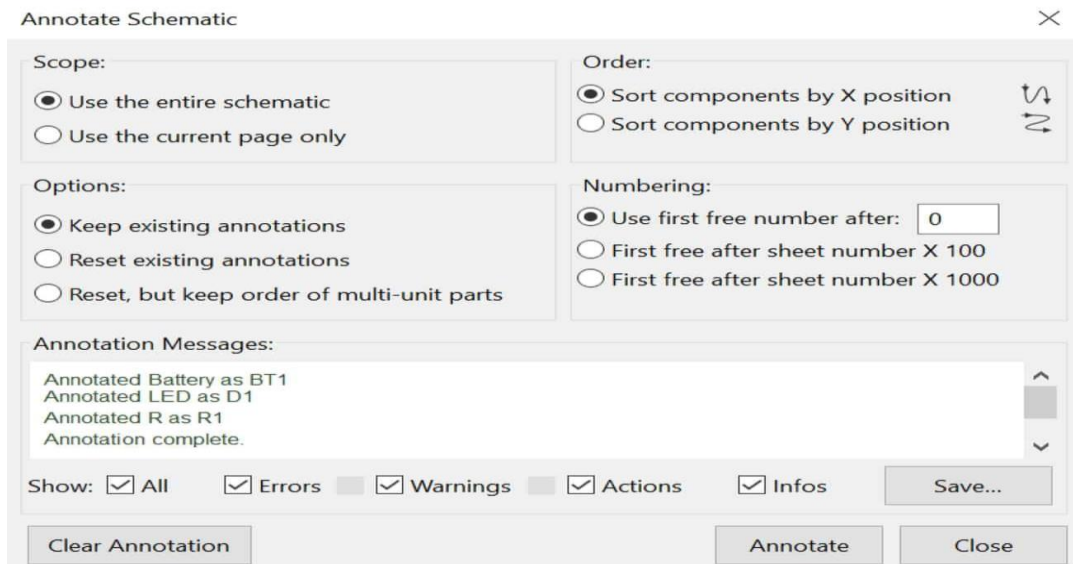


**Figure 12.11** The window for editing the component value

- To set a resistor value to 470  $\Omega$ , you would normally write “470”. And to set the battery value to 9 volts, it is normal to write “9V”. For the LED you could, for example, write “2V RED” or something similar to indicate that you want to use a red LED with 2V forward voltage.
- Note that the value you set for a component does nothing to your circuit. It just serves as a reminder for you, so that you’ll remember what value to use when you build the circuit.

## 6. Annotating the Schematic

- The next step is to Annotate your schematic, which means to give the components a unique identifier. For example, if you have several resistors, they will be named R1, R2, R3, and so on.
- To do this, click on the *Tools* menu, then choose *Annotate Schematic*.

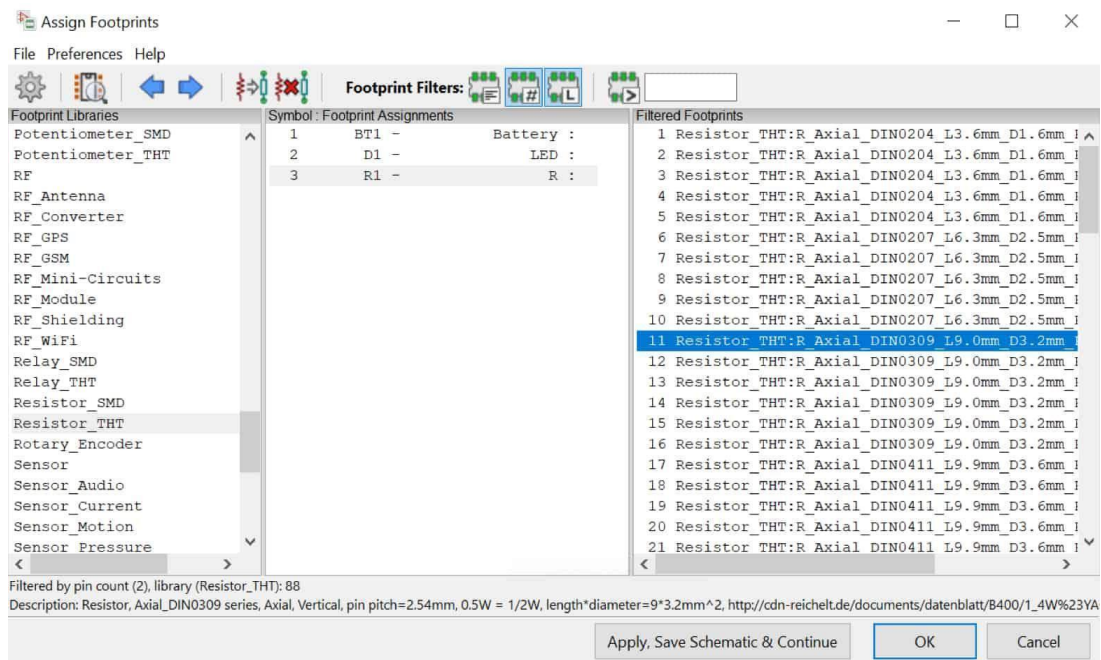


**Figure 12.12** Annotate schematic

- Leave the default options and click on the **Annotate** button. Then close the window.
- Now you can see that the components have numbers: **BT1**, **R1**, and **D1**.

## 7. Adding Footprints

- Before you can move on to drawing your board, there is one more thing you need to do; add *footprints* to your components.
- The footprint is what will be printed onto the board for each component.
- For example, for a through-hole resistor, you will choose a footprint with two holes, so that you will get two holes for soldering the resistor onto your board.
- Click on the *Tools* menu and choose *Assign footprints*



**Figure 12.13** The footprint selector

- Figure 12.13 shows the footprint selector. On the left side, you see all the footprint libraries you have available. In the middle, you have the components from your schematic. And on the right, you have a list of footprint options to choose from.
- To see what a footprint looks like, right-click on it and select *View Footprint*.



**Figure 12.14** An example of a footprint for a resistor. The yellow circles represent holes.

- Filters help you narrow it down
- There are a lot of footprints in KiCad.
- But on the toolbar, you have filters to choose from to help you narrow down your options:



**Figure 12.15 The Footprint Filter Selector**

- If you *filter by pin count* you will only see footprints that have the same number of pins as your component.
  - If you *filter by library* you will only see footprints from the library that you have selected on the left.
  - The *schematic symbol footprint filter* will filter based on filtering rules set by the symbol.
- What footprint to choose for the battery?

- There are many ways to connect a battery. You can use a battery holder that is fixed onto the board. You can use a barrel connector. Or how about two pins?
- For 9V batteries though, prefer using a battery clip. It is a clip you fasten to the top of the battery that has two wires going from it.

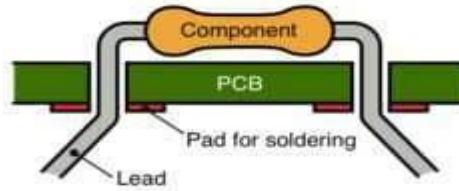


**Figure 12.16 A battery clip for connecting 9V batteries**

- Such a clip does not exist in KiCad at the time of writing. But all you need is a couple of holes where you can solder the wires from the clip. If you add a pin header with two pins, the footprint will be two holes.
- You can find pin headers for example in the *Connector\_PinHeader\_2.54mm* library.
- There are a few options here. Have a look at a couple of them by right-clicking and choosing *View Footprint*. Then click on the **3D Display** button to see what it looks like in 3D.
- Remember that it does not matter which one you choose, as long as it adds two holes to your board. Double-click a footprint to choose it.

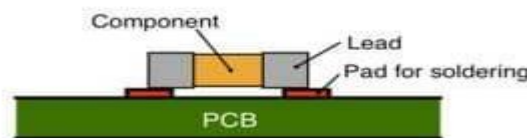
What footprint to choose for the resistor?

- You will find two resistor libraries among the standard KiCad libraries: *Resistor\_THT* and *Resistor\_SMD*.
- *THT* stands for *Through-Hole Technology*. That's the type of component where you put the legs into holes on the board and solder on the other side as shown in Figure 12.17. It is the classic type of component, often used by students as it is a bit simpler to solder.



**Figure 12.17 Through Hole Technology (THT)**

- *SMD* stands for *Surface Mount Device*. That is the type of component that lies on top of the board. You solder them on the same side, as shown in Figure 12.18 SMD is the standard component type for modern electronics. They are smaller and take up less space.



**Figure 12.18 Surface Mounted Device (SMD)**

- For this circuit use Through-Hole Components, so select the *Resistor THT* library.
- There are tons of options. But note that it is not very important which option you choose here. All of them will give you two holes on the board to solder your resistor into.
- But if you want the perfect fit, measure the resistor you plan to use – or look at its size specification from the store where you plan to buy it. Then choose the closest match you can find.

What footprint to choose for the LED?

- The last component is the LED. Choose the *LED\_THT* library to add a through-hole LED.
- A typical LED is 5mm in diameter. There are many 5mm options in the library. A lot of them have the same footprint but different 3D models. Have a look at the 3D version of a couple of them to get an idea of the difference. (Right-click and select *View Footprint*. Then click on the *3D Display* button.)
- Double-click to choose one. You can see sample footprint selections in Figure 12.19



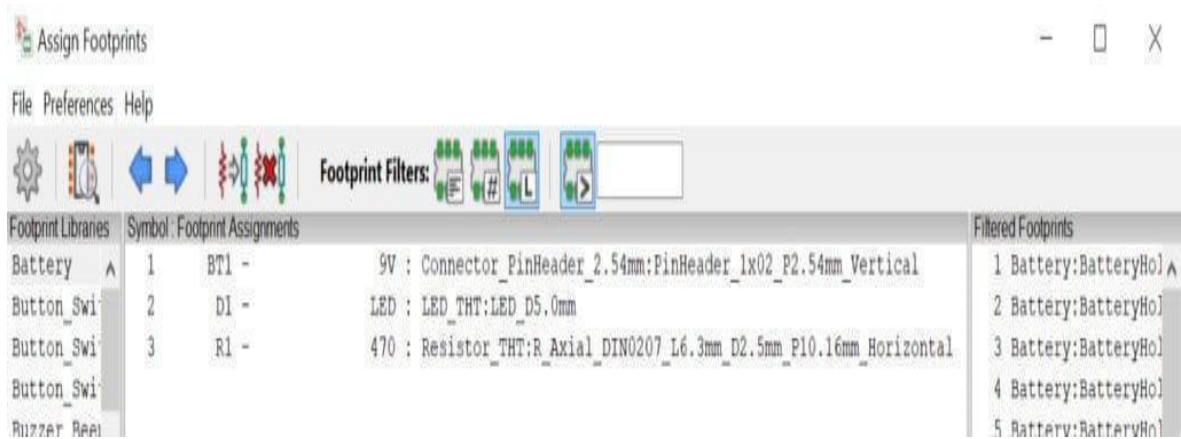


Figure 12.19 Sample footprint selections for this circuit

## 8. Running the Electrical Rules Check

- It is easy to make errors, like forgetting to connect a component. Especially when you are drawing large circuits. To help you find these errors, use the tool *Electrical Rules Check (ERC)*.
- Click on the *Inspect* menu and choose *Electrical Rules Check*. Or click on the **Perform Electrical Rules Check** button shown in Figure 12.20



Figure 12.20 The Perform Electrical Rules check button

In the window that pops up, click on the **Run** button and look for error messages under *Error List*. A typical error here is if you forgot to connect the pin of a component to another component. Or if you accidentally moved a component so that it's no longer connected.

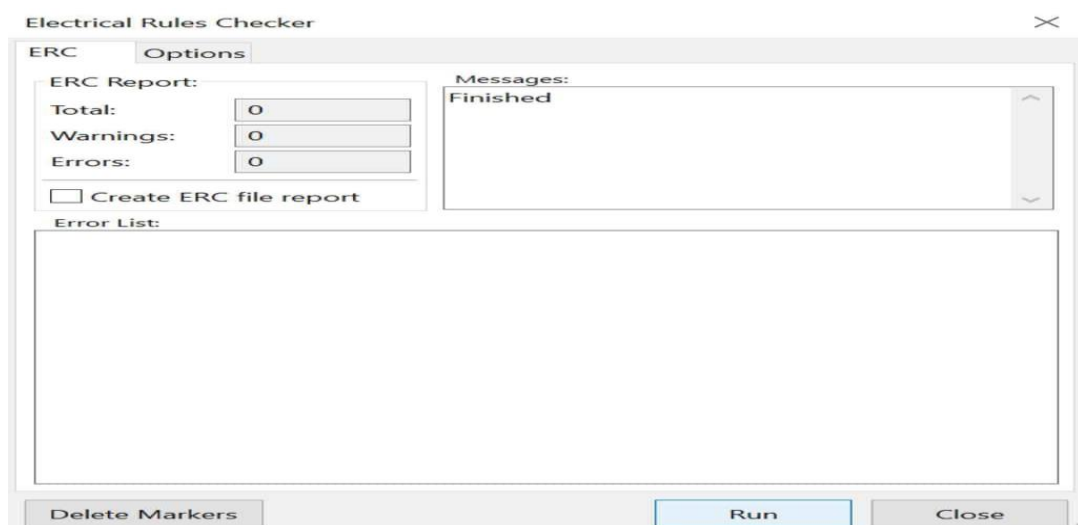


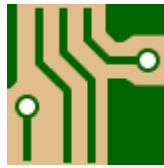
Figure 12.21 The Electrical Rules Checker window

- If there are no errors, you have finished the first phase of drawing the schematic. You can move on to the second phase – designing your board.

## PART 2 - LAYING OUT A CIRCUIT BOARD

### 9. Starting a New Board Layout

- You have defined how you want to connect the components in the schematic editor, and now it is time to put that on your board. You need to decide where to place the components, then draw tracks to create the connections between them.
- To start drawing your board layout (assuming you're still in the Schematics Editor), click on the toolbar button that says **Run Pcbnew to layout printed circuit board** as shown in Figure 12.22 Or go to the *Tools* menu and select *Open PCB Editor*. This opens up the *Board Editor* window.



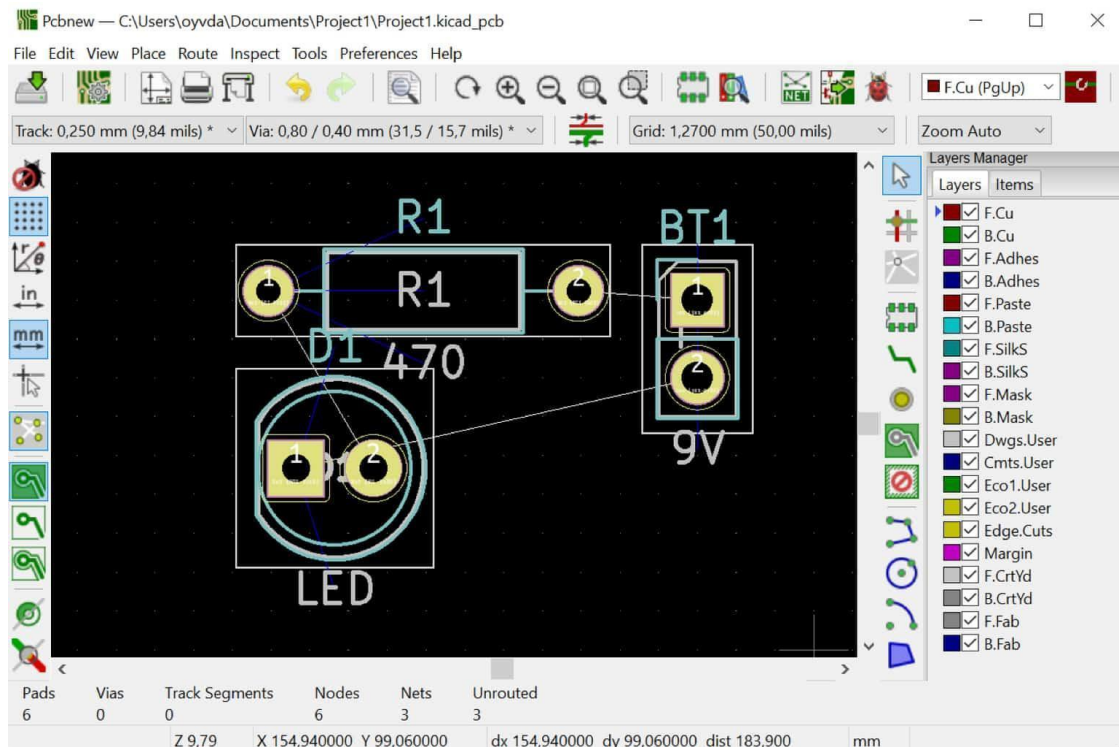
**Figure 12.22 The button to go from schematic design to board layout**

- The first thing you will see is just an empty area.
- To get started, you need to retrieve information about footprints and connections from your schematic. You can do this by clicking on the toolbar button that says **Update PCB from schematic** as shown in Figure 12.23 You'll also find this option in the *Tools* menu.



**Figure 12.23 The button to update PCB from schematic**

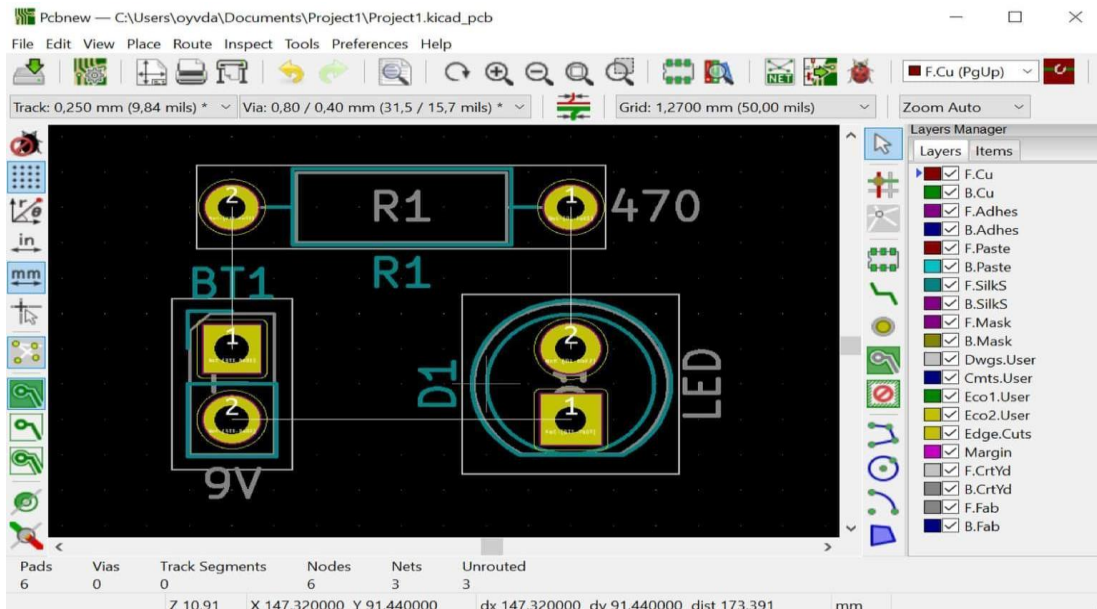
- A window will pop up.
- Keep the default options and click on the **Update PCB** button. This will load your footprints. Then click on the **Close** button.
- Click anywhere to place the components.
- If you zoom in on the components, using either your mouse-wheel or F1/F2, you will see white straight lines between the pins. These are called *air-wires* and tell you which pins to connect – according to your schematic.



**Figure 12.24** The components imported from the schematic

## 10. Positioning the Components

- Your next task is to position your components so that it becomes easy to connect the components according to your air-wires. If you are able to place the components in a way that no air-wires cross, that is the easiest.
- I recommend positioning the components like the way you did in the schematic, if possible. It is not very important for such a simple board, but for more complicated boards it can simplify troubleshooting.
- To move a component, move your mouse over it and press **M**. If you already have a group selected, the whole group will move. To deselect the group, press **ESCAPE**. To rotate a component, press **R**.
- If you accidentally place your mouse over the component name, you will move only the name. Just press **ESCAPE** to try again.



**Figure 12.25** The components placed so that no air-wires cross

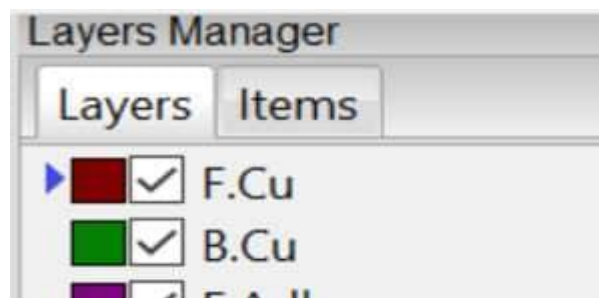
### 11. Drawing the Tracks

- The next step is to replace the air-wires by drawing tracks to connect the components. The tracks you draw will become copper traces on your finished board.
- Start drawing tracks by clicking on the *Route Tracks* button on the toolbar on the right (shown in Figure 12.26) or press **X** on your keyboard.



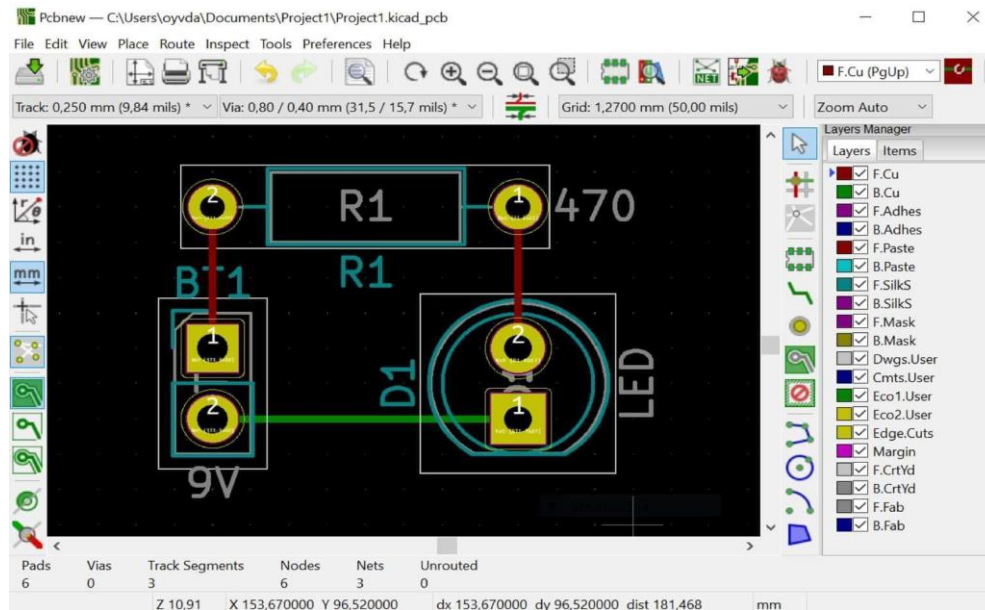
**Figure 12.26** The button for routing tracks

- You can choose if you want to draw on the front or the back of the board, by selecting a layer in the *Layer Manager*. The little blue triangle on the left shows the selected layer.
- **F.CU** is the front (or top) side.
- **B.CU** is the back (or bottom) side.



**Figure 12.27** The layers manager

- Click at the beginning of an air-wire to start drawing a track. Click again where the air-wire ends to finish drawing the track.
- When there are no more white lines, you are done routing the tracks.



**Figure 12.28** The board with all its tracks routed

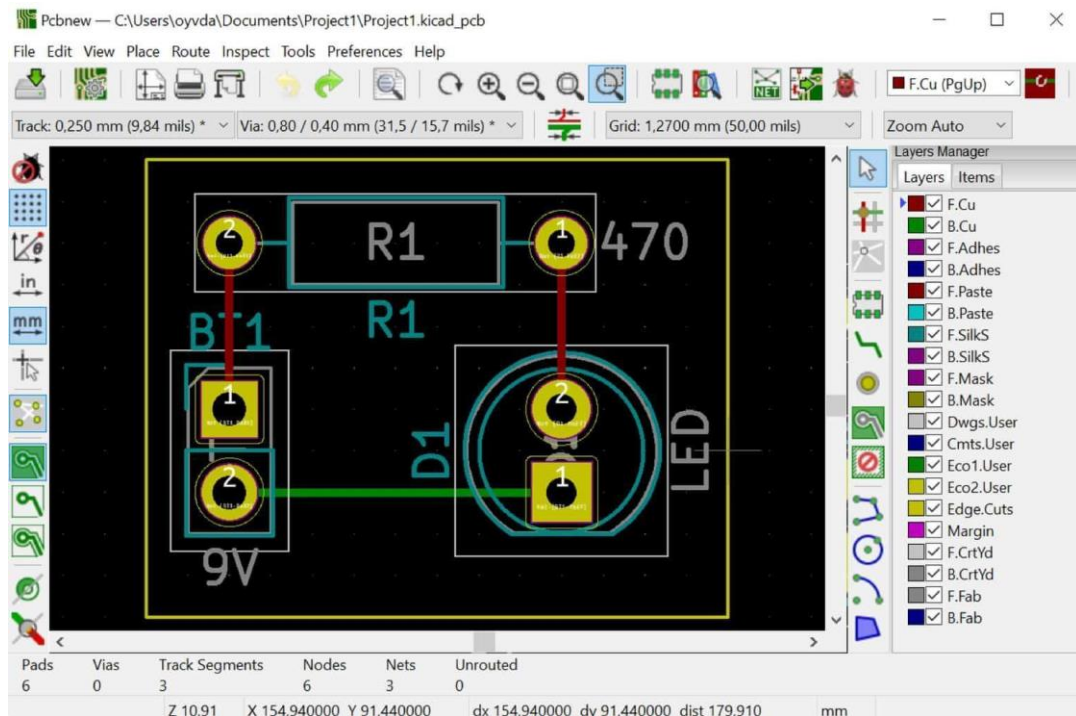
## 12. Drawing Your Board Outline

- Next, draw the outline of your board. To do this, you need to add a polygon on the **Edge.Cuts** layer.
- Click on the *Add graphic polygon* button on the toolbar, as shown in Figure 12.28



**Figure 12.29** The button for adding a polygon

- Select the **Edge.Cuts** layer.
- Click to start drawing the polygon. Click again for each corner. To complete the polygon, click at the point where you started.



**Figure 12.30** The board with the board outline added

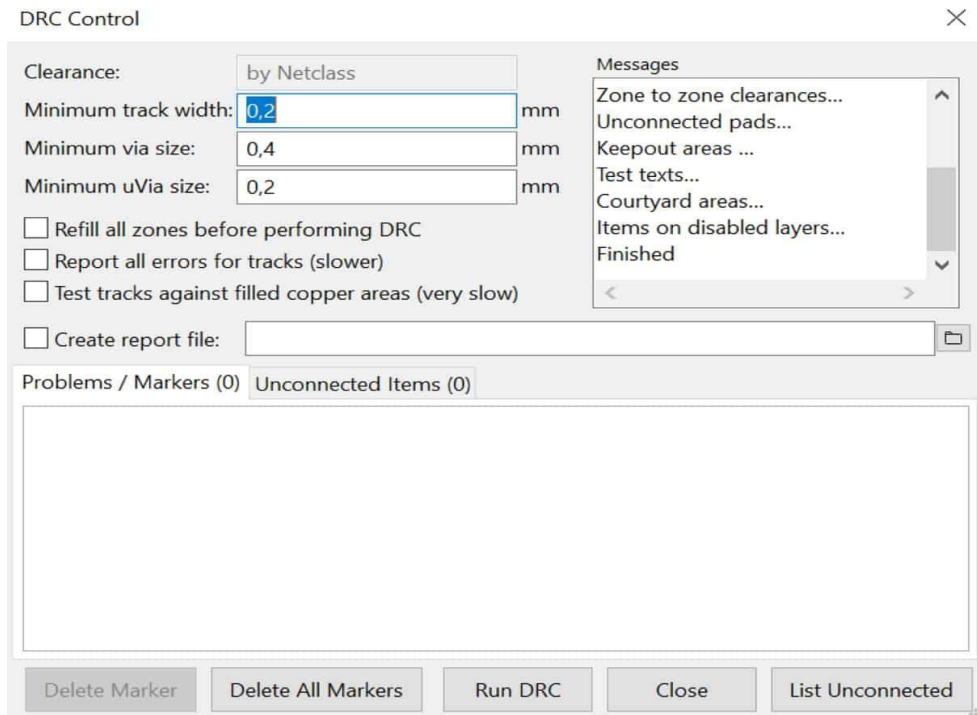
### 13. Running the Design Rules Check

- To check if you have made any errors, you need to run the *Design Rules Checker* – also called the *DRC*. Typical errors are placing two components too close to each other, or forgetting to draw a track.



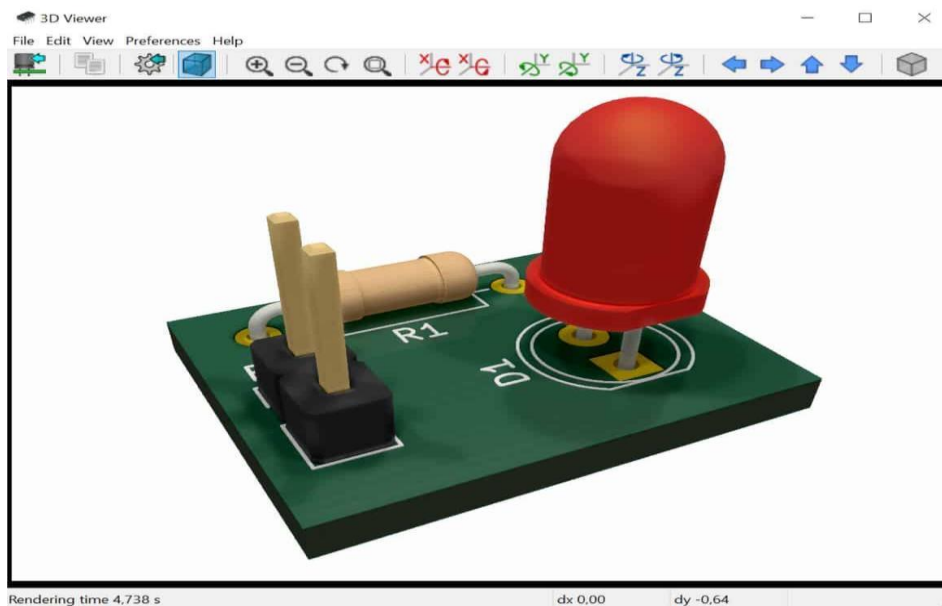
**Figure 12.31** The button for running the Design Rules Checker (DRC)

- Select the **Edge.Cuts** layer.
- Click on the *Design Rules Checker* button, shown in Figure 12.31, or find it under the *Inspect* menu. Leave the default options and click on *Run DRC* button.
- Check both the *Problems* tab and the *Unconnected Items* tab. The *Problems* tab will list any design issues, such as a track being too close to another track. The *Unconnected Items* tab will list any air-wires that you have not yet connected by drawing a track.



**Figure 12.32 The Design Rules Checker window without any errors**

- If you see any items on any of these tabs, make sure you fix them before moving on.
- **If you have errors**, fix them and run the DRC again.
- When you have zero errors listed here, **Your board is finished!**
- Click on the *View* menu and select *3D Viewer* to see your finished board.



**Figure 12.33 3D view of the finished board**

#### **14. Generate Gerber file**

- Once your circuit design is complete, you have to generate Gerber files and Drill files.
- From the PCB Editor in KiCad you can create Gerber files by going to the *File* menu and selecting *Plot*.
- To create Drill files, click on **Generate Drill Files**.
- These files can be submitted to PCB manufacturers for PCB production.

#### **XI Observations:**

**Picture of the designed circuit in KiCad (eagle/ PCB/ Dip trace/ DesignSpark PCB):**

**Picture of the designed PCB in KiCad(eagle/ PCB/ Dip trace/ Design Spark PCB):**



**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation**

.....  
.....

**XV Practical related questions**

1. State significance of the open source PCB design simulation software?
2. List the advantages of PCB design simulation software over conventional methods of PCB designing.
3. State different open source PCB design simulation softwares.
4. State the importance of DRC (Design Rules Checker).

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....



**XVI References/Suggestions for further reading: include websites/links**

1. <http://kicad.org/download/>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

**Practical No.13: Identify types of PCB****I Practical Significance:**

The acronym PCB stands for Printed Circuit Board. PCBs are the backbone of most electronics industries. PCBs offer several advantages including compact design, improved reliability, reduced electronic noise, ease of mass production and efficient heat dissipation. They streamline the assembly process, enhance electrical performance, and enable miniaturization of electronic devices. PCBs enhance reliability by minimizing loose connections and reducing the risk of short circuits. The standardized design and automated manufacturing processes ensure consistent quality. Additionally, the soldering of components onto the PCB improves their stability and durability.

**II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Develop the PCB for the given application.

**IV Laboratory Learning outcome(s)**

Identification of types of PCB.

**V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

**VI Relevant Theoretical Background**

PCB- A printed circuit board (PCB) is a non-conductive substrate used to mechanically support and electrically connect electronic components using conductive pathways or traces etched from copper sheets laminated onto the substrate. PCBs provide the foundation for almost all modern electronic equipment and enable the physical implementation, connectivity and packaging of circuit designs. PCBs are most commonly made from fiberglass, composite epoxy or another composite material.

Key elements of a PCB include:

1. Substrate material – commonly FR-4 glass epoxy or other insulating material
2. Conductive layers – copper foils laminated on substrate to create signal traces
3. Pads/lands – widened areas of copper traces for soldering components
4. Plated through holes (PTHs) – plated barrel interconnects between layers
5. Solder mask – insulating layer covering exposed copper from oxidation and short circuits
6. Silkscreen – printed component outlines and identifiers

PCBs are designed to meet specific requirements and applications for industrial, consumer and other appliances. Different Types of PCBs are as follows.

According to number of layers PCBs are classified as,

1. Single Layer PCB
2. Double Layer PCB
3. Multilayer PCB

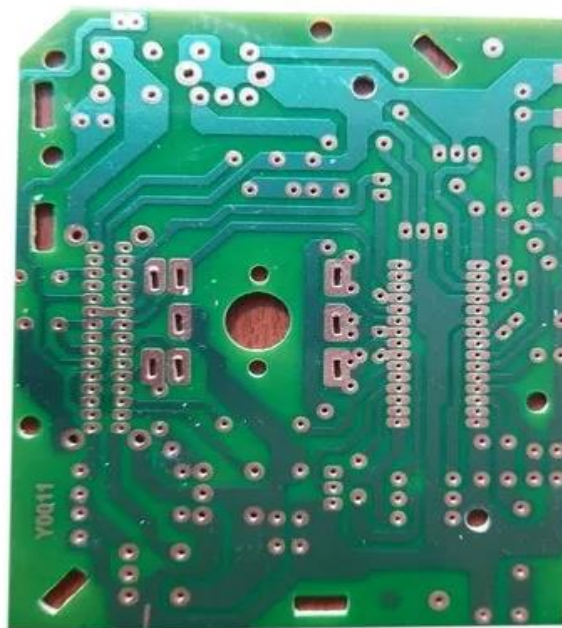
#### 1. Single Layer PCB:



**Figure 13.1 Single Layer PCB**

The number of layers in a PCB is the number of conductive or copper layers it has. A PCB with one conductive layer to create a circuit is known as a Single Layer PCB. These PCBs are made up of a rigid material such as fiberglass (FR-4).

A Single Layer PCB is the simplest PCB as there is only one conductive layer. It is widely used in applications where compact circuits are needed. They are used in calculators, radios, power supplies, etc.



**Figure 13.2 Actual Single Layer PCB**

## 2. Double Layer PCB:



**Figure 13.3 Double Layer PCB**

A double-layer PCB has two conductive layers: one at the top surface and one at the bottom of the PCB. It means the circuit and components can be on two sides. They are used for tasks where single-layer PCBs cannot work. It is extremely useful in many electronic applications because circuits on one side of the board can be connected on the other side of the board with the help of holes drilled on the board called vias.

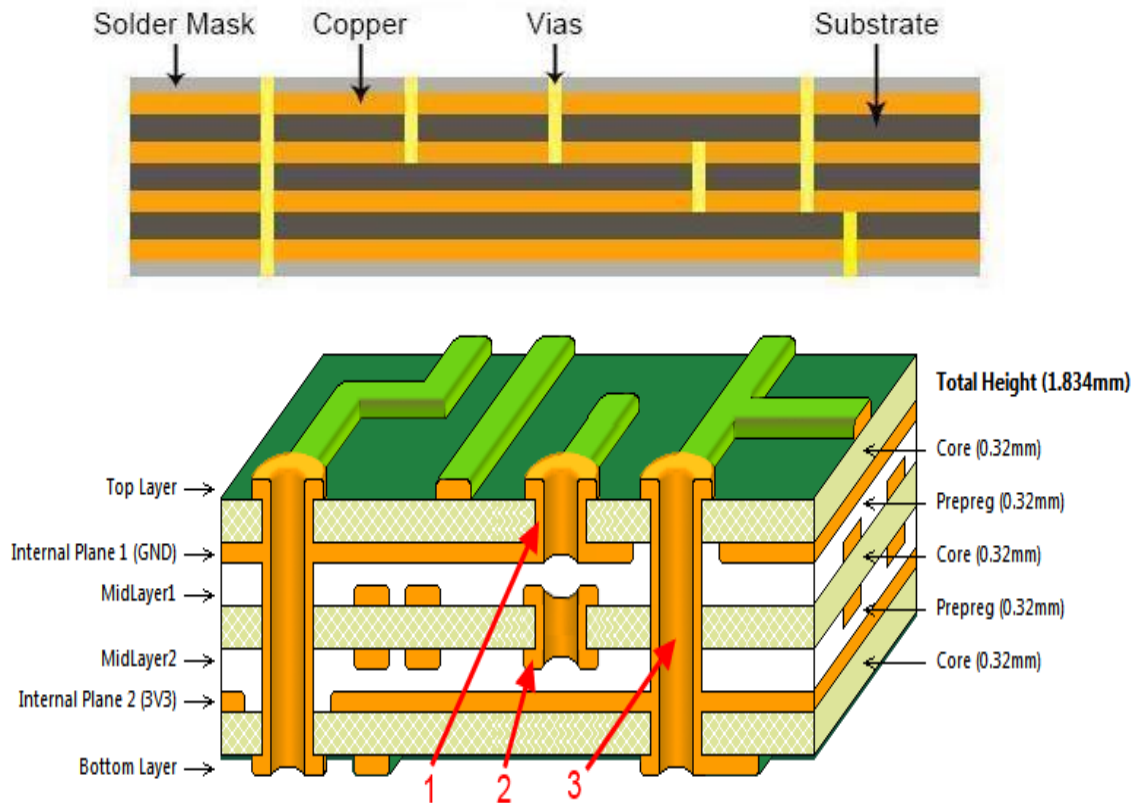
Advantages of Double Layer PCB are increased component density, flexible routing options, improved signal integrity, and overall optimized layout.

A Double Layer PCB is suitable for moderate complexity applications. They are used in medical devices, consumer appliances, HVAC systems, vending machines etc.



**Figure 13.4 Actual Double layer PCB**

### 3. Multilayer PCB:

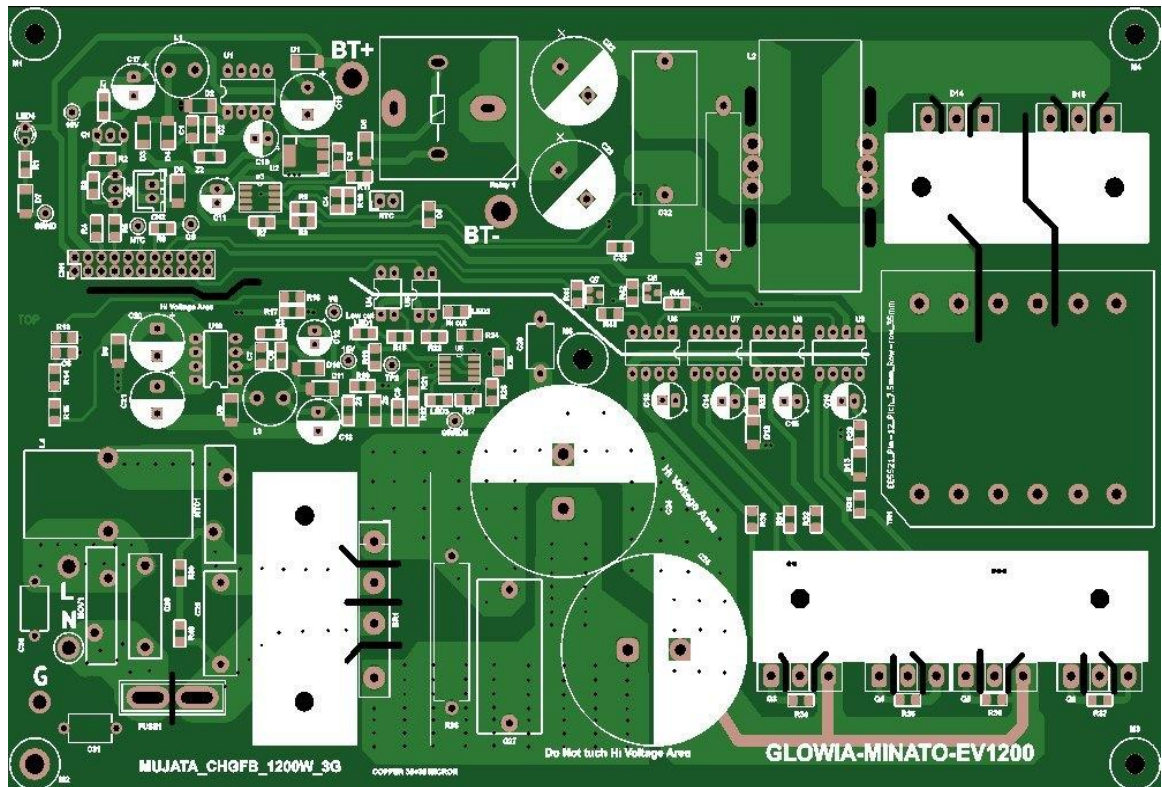


**Figure 13.5 Multilayer PCB**

A multilayer PCB is a printed circuit board with at least three conductive layers. The electrical connection between multilayer printed circuit board layers is realized using plated through holes on the circuit board. The number of layers of a Multilayer circuit board can be 4, 6, 8, 10 up to 100 layers.

Multilayer PCBs have more copper conductive layers and more wiring space, and the design of multilayer PCBs can achieve better signal transmission and electrical performance. The multilayer PCB manufacturing process requires more attention to detail. Multilayer PCBs achieve electrical connections between different layers through plated via holes, buried holes, or blind holes.

Multilayer PCBs enable more and more complex applications. They are used in computers, Industrial control circuits, Satellite systems etc.



**Figure 13.6 Actual multilayer PCB**

According to the nature of the PCB substrate, PCBs are classified as,

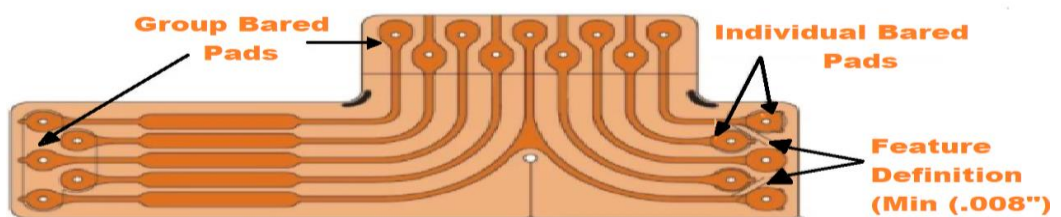
1. Rigid PCB
2. Flexible PCB
3. Rigid-Flexible PCB

#### 1. Rigid PCB :

Rigid PCBs are made out of a solid and inflexible substrate material such as fiberglass that prevents the board from twisting. Example of a rigid PCB is a computer motherboard. The motherboard is a multilayer PCB designed to allocate electricity from the power supply while simultaneously allowing communication between all of the many parts of the computer, such as CPU, GPU and RAM.

All Rigid PCBs have single-layer, double-layer or multilayer constructions, so they all share the same applications.

#### 2. Flexible PCB:



**Figure 13.7 Flexible PCB**

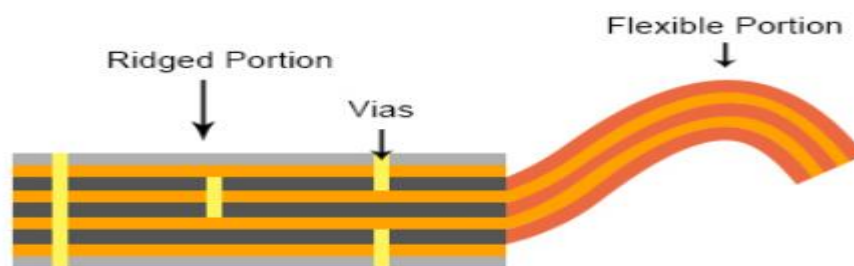


Flexible PCBs can flex and move or twisted without damaging the circuits. This means they can be folded over edges and wrapped around corners. Flexible PCB is made of flexible substrate materials such as plastic (thin insulating polymer film), polyimide etc. Lower thickness, space saving, reduced weight and size, increased freedom in designing, low number of device interconnects, shock and vibration resistant, easy transportation, these benefits make flexible PCBs ideally fit for a wide range of applications in industries such as Military, Transportation, Medical, Consumer Electronics, Automotive, Aerospace, Communications.



**Figure 13.8 Actual Flexible PCB**

### 3. Rigid-Flexible PCB:



**Figure 13.9 Rigid-Flexible PCB**

Rigid-flexible boards combine the features of rigid and flexible PCBs, incorporating both rigid and flexible sections within the same board. The combination of rigid and flexible boards into a single rigid-flex board allows for a more streamlined design, reducing the overall board size and package weight.

Flex-rigid PCBs are most often found in applications where space or weight are prime concerns, including Cell phones, Digital cameras, Pacemakers and Automobiles.

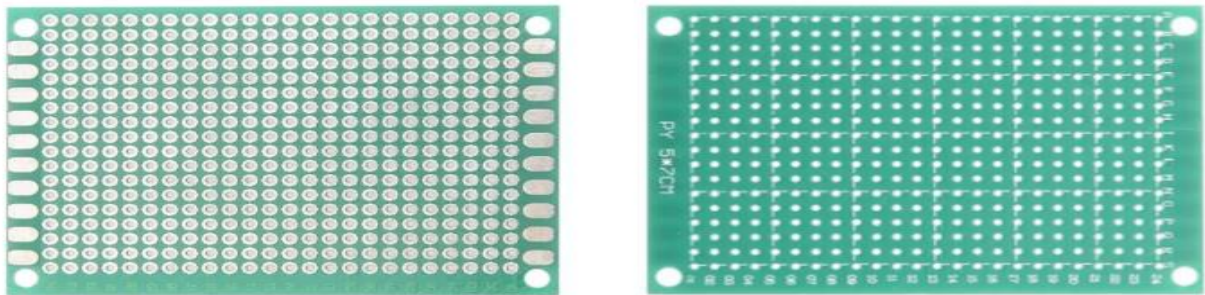


**Figure 13.10 Actual Rigid Flexible PCB**

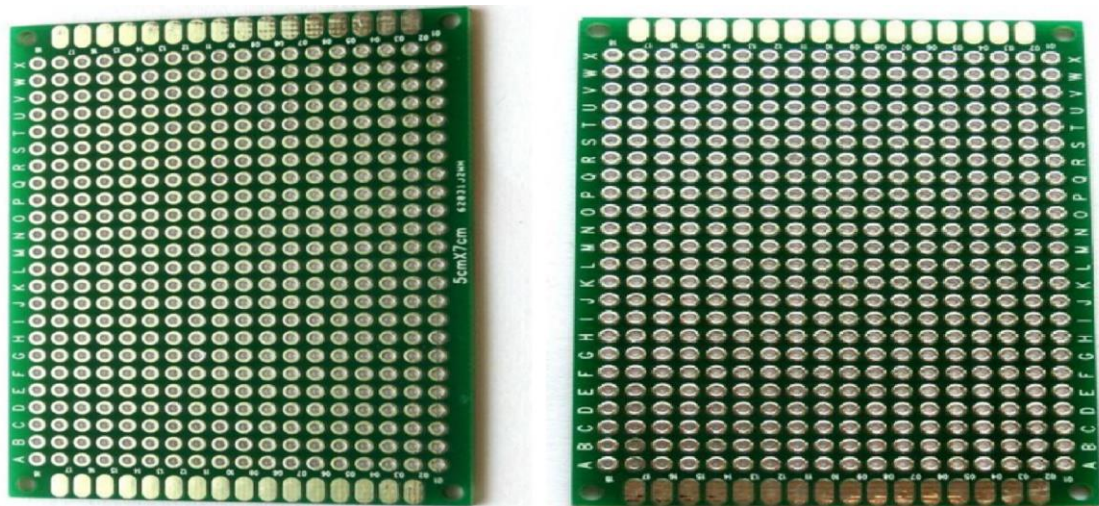
**VII Actual tools / Circuit diagram used in a laboratory with equipment specifications.**



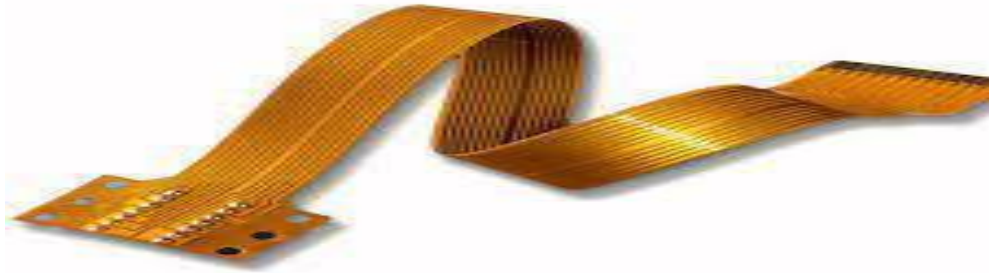
**Figure 13.11 3x2 inches Phenolic Single Sided Plain Copper Clad Board (PCB)**



**Figure 13.12 5x7 cm Single Sided Universal PCB Prototype Board**



**Figure 13.13 5x7cm Double Sided Universal PCB Prototype Board**



**Figure 13.14 Flexible PCB**

### VIII Required Resources/apparatus/equipment with specifications

Sr. No.	Instrument/ Components	Specification	Quantity	Remark
1	Single Sided PCB	3x2 inches or available size Phenolic Single Sided Plain Copper Clad Board (PCB), 5x7 cm or available size Single Side Prototype Board.	1 each	
2	Double Sided PCB	5x7 cm or available size Double Sided Universal PCB Prototype Board	1	
3	Flexible PCB	Available size or used in any application	1	

### IX Precautions to be followed:

1. Handle PCBs with care.

### X Procedure:

#### A. Steps for PCB Identification

1. Observe the given PCB.
2. Identify solder side and component side.
3. Observe base material.
4. Observe the tracks.
5. Identify the type of PCB.

**XI Observation table:**

**Table 1: Identification of types of PCBs**

Sr. No	PCB No.	Type of PCB (Single Sided Plain PCB/ Single Sided prototype/ Double Sided/ Flexible)
1	1	
2	2	
3	3	
4	4	

**XII Result(s)**

.....

.....

**XIII Interpretation of results**

.....

.....

**XIV Conclusions and recommendation**

.....

.....

**XV Practical related questions**

1. List types of PCBs.
2. List the applications of flexible PCB.
3. State how tracks are connected in multilayer PCB.
4. Suggest base material for PCB with their applications and reasons.

**Answers:**

.....

.....

.....



**XVI References/Suggestions for further reading: include websites/links**

- 1 <https://www.pcbelec.com/pcb-manufacturing/single-layer-pcb>
- 2 <https://electronicsmaker.com/pcb-testing-challenges-solutions>
- 3 [https://en.wikipedia.org/wiki/Printed\\_circuit\\_board#Types](https://en.wikipedia.org/wiki/Printed_circuit_board#Types)
- 4 <https://www.pcbcart.com/article/content/PCB-introduction.html>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

### **Practical No.14: Characteristics of the solar cell**

#### **I Practical significance:**

Solar cells, also known as photovoltaic cells, are devices that convert light energy directly into electricity through the photovoltaic effect. They are a key technology in renewable energy systems, allowing for the harnessing of sunlight to generate electricity.

Solar cells are often grouped together to form solar panels or solar arrays, which can be installed on rooftops, in solar farms, or integrated into various devices to provide clean and renewable electricity. They play a crucial role in the transition to sustainable energy sources and reducing dependence on fossil fuels.

#### **II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

#### **III Course Level Learning outcome(s)**

Use specific components for roof top Solar Energy Systems

#### **IV Laboratory Learning outcome(s)**

Plot V-I Characteristics of the solar cell.

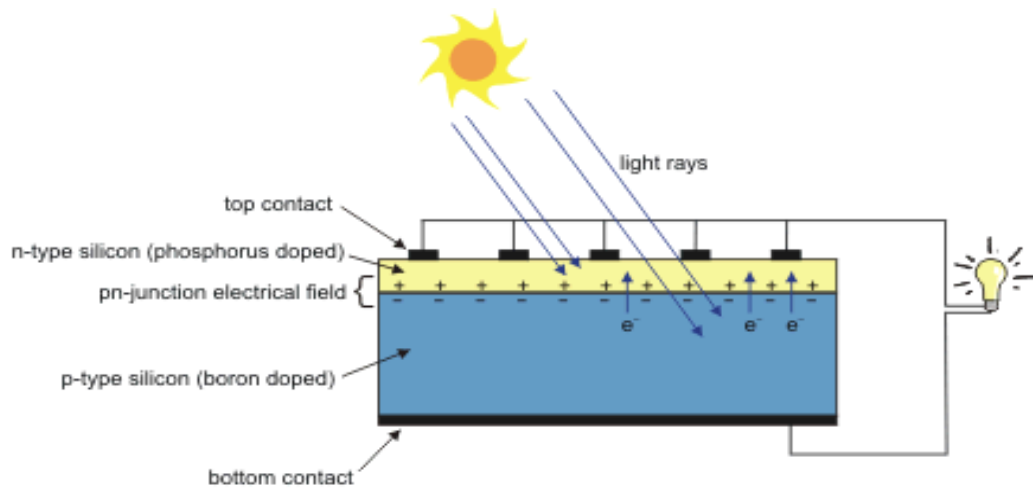
#### **V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

#### **VI Relevant Theoretical Background**

Solar cells are typically made of semiconductor materials such as silicon, which are capable of absorbing photons (light particles) and releasing electrons, creating an electric current. When sunlight hits the solar cell, photons transfer their energy to electrons in the semiconductor material, causing them to become mobile and generate an electric current.

There are several types of solar cells, including monocrystalline, polycrystalline, and thin-film solar cells, each with its own advantages and disadvantages in terms of efficiency, cost, and manufacturing process.



**Figure 14.1 Working principle of a solar Cell**

### V-I characteristics of Solar cell

The V-I (voltage-current) characteristics of a solar cell describe its behavior in terms of voltage and current under different conditions of load resistance.

**Open Circuit Condition ( $V_{oc}$ ):** When no load is connected to the solar cell, the voltage across the terminals is at its maximum value, known as the open-circuit voltage ( $V_{oc}$ ). At this point, the current is zero because there is no external circuit for the electrons to flow through.

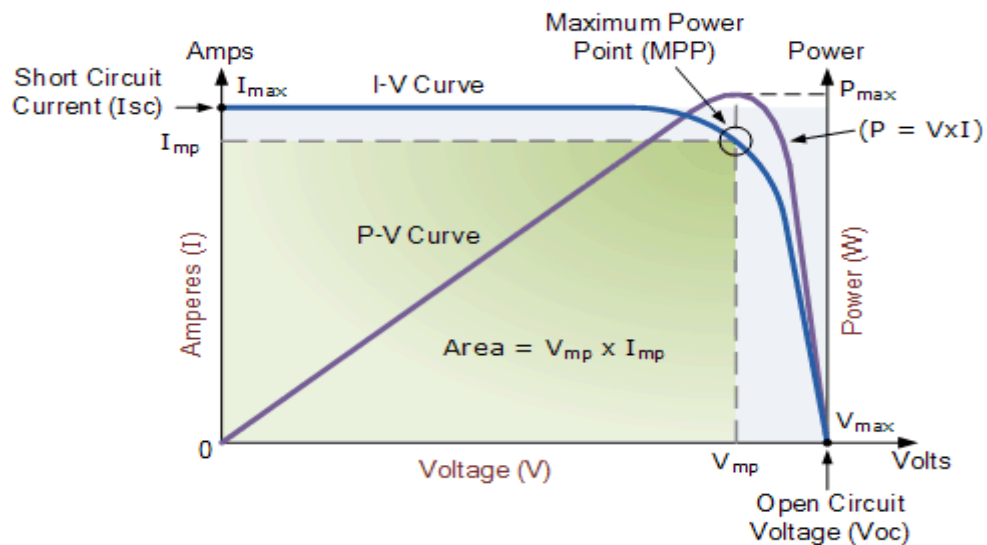
**Short Circuit Condition ( $I_{sc}$ ):** In the short circuit condition, where the terminals of the solar cell are directly connected without any load resistance, the current is at its maximum value, known as the short-circuit current ( $I_{sc}$ ). At this point, the voltage across the terminals is zero because the circuit is effectively shorted.

**Operating Point ( $V_{mp}$ ,  $I_{mp}$ ):** In practical applications, the solar cell operates at a point between the open-circuit and short-circuit conditions, known as the maximum power point (MPP). At this point, both the voltage and current are at intermediate values, denoted as  $V_{mp}$  (voltage at maximum power) and  $I_{mp}$  (current at maximum power). The solar cell delivers the maximum power output to the load at this operating point.

Understanding the V-I characteristics is crucial for designing and optimizing solar photovoltaic systems to ensure maximum efficiency and power output under varying operating conditions. These characteristics help engineers and researchers evaluate the performance of solar cells and predict their behaviour in different environments.



A V-I characteristic of a solar cell is as shown in Figure 14.2



**Figure 14.2 V-I Characteristics of Solar cell**

The electromotive force (e.m.f.) generated by the photo-voltaic cell in the open circuit, i.e. when no current is drawn from it is denoted by  $V_{OC}$  (V-open circuit). This is the maximum value of electromotive force (e.m.f.). When a high resistance is introduced in the external circuit, a small current flows through it and the voltage decreases.

The voltage goes on falling and the current goes on increasing as the resistance in the external circuit is reduced. When the resistance is reduced to zero the current rises to its maximum value known as saturation current and is denoted as  $I_{SC}$ , the voltage becomes zero.

#### **Determination of fill factor:**

The product of open circuit voltage  $V_{OC}$  and short circuit current  $I_{SC}$  is known as an ideal power.

$$\text{Ideal Power} = V_{OC} \times I_{SC}$$

The maximum useful power is the area of the largest rectangle that can be formed under the V-I curve. If  $V_{mp}$  and  $I_{mp}$  are the values of voltage and current under this condition, then,

$$\text{Maximum useful power, } P_{max} = V_{mp} \times I_{mp}$$

The ratio of the maximum useful power to ideal power is called the fill factor.

$$\text{Fill factor} = (V_{OC} \times I_{SC}) / (V_{mp} \times I_{mp})$$

## VII Actual Circuit diagram used in laboratory with equipment specifications.

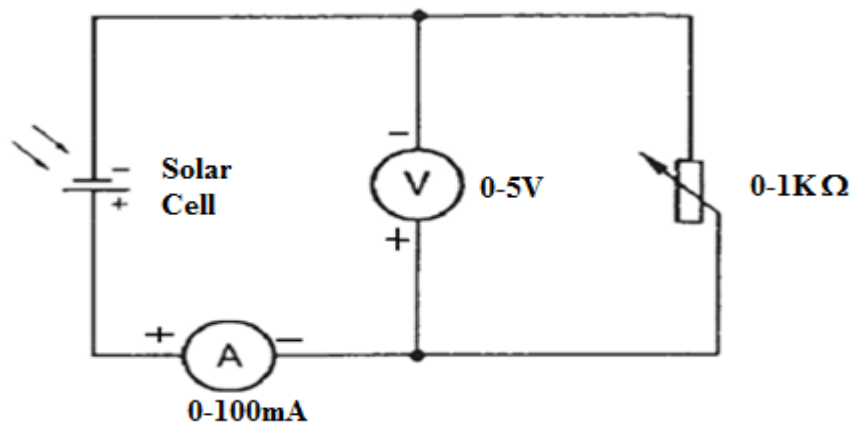


Figure 14.3 Circuit diagram for Solar Cell Characteristics



Figure 14.4 Experimental Set-up for Solar Cell Characteristics

## VIII Required Resources/apparatus/equipment with specifications.

Sr. No.	Instrument/Components	Specification	Quantity	Remark
1	Voltmeter/Multimeter	0-5V	1	
2	Microammeter/Multimeter	0-100mA	1	
3	Solar cell	4.5V, 100mA	1	
4	Light source	100 watt lamp	1	
5	Variable resistor	0-1KΩ	1	

## IX Precautions to be followed:

1. Connect voltmeter and ammeter in correct polarities.
2. Light from the lamp should fall normally on the cell.
3. A resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

**X Procedure:**

1. Place the solar cell and the light source (100 watt lamp) opposite to each other on a wooden plank. Connect the circuit as shown in Figure 14.3
2. Select the voltmeter range to 5V, current meter range to 100mA
3. Switch ON the lamp to expose the light on the Solar Cell
4. Set the distance between the solar cell and lamp in such a way that the current meter shows maximum deflection.
5. Keep resistance maximum (disconnect the resistance, make open circuit) and note down open circuit voltage,  $V_{OC}$ .
6. Keep load resistance minimum and note down short circuit current,  $I_{SC}$ .
7. Vary the load resistance and note down the current and voltage readings in Table1.
8. Plot a graph between output voltage vs. output current by taking voltage along X-axis and current along the Y-axis.

**XI Observation table:**

1. Voltage reading for open circuit,  $V_{OC} = \dots\dots\dots$ Volts.
2. Current reading with zero resistance,  $I_{SC} = \dots\dots\dots$ mA.

**Table 1: V-I characteristics of Solar cell**

Sr. No.	Load Resistance ( $R_L$ )	Voltage (V)	Current (mA)	Power(mW)
1	10 $\Omega$			
2	20 $\Omega$			
3	50 $\Omega$			
4	100 $\Omega$			
5	200 $\Omega$			
6	400 $\Omega$			
7	700 $\Omega$			
8	1K $\Omega$			

**Calculations:**

From the Graph:

1. Value of  $V_{mp} = \dots\dots\dots$  volts
2. Value of  $I_{mp} = \dots\dots\dots$  mA
3. Maximum useful power =  $V_{mp} \times I_{mp} = \dots\dots\dots$  mW
4. Ideal power  $V_{OC} \times I_{SC} = \dots\dots\dots$  mW
5. Fill factor =  $(V_{OC} \times I_{SC}) / (V_{mp} \times I_{mp}) = \dots\dots\dots$

**XII Result(s)**

.....  
.....

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation:**

.....  
.....

**XV Practical related questions**

1. Compare a solar cell and a photodiode on the basis of Size, energy source, cost, mode of operation and applications.
2. List the types of semiconductor materials used for solar cells.
3. Define Dark current.
4. Define photovoltaic effect.

**Answers:**

.....  
.....  
.....  
.....  
.....  
.....  
.....



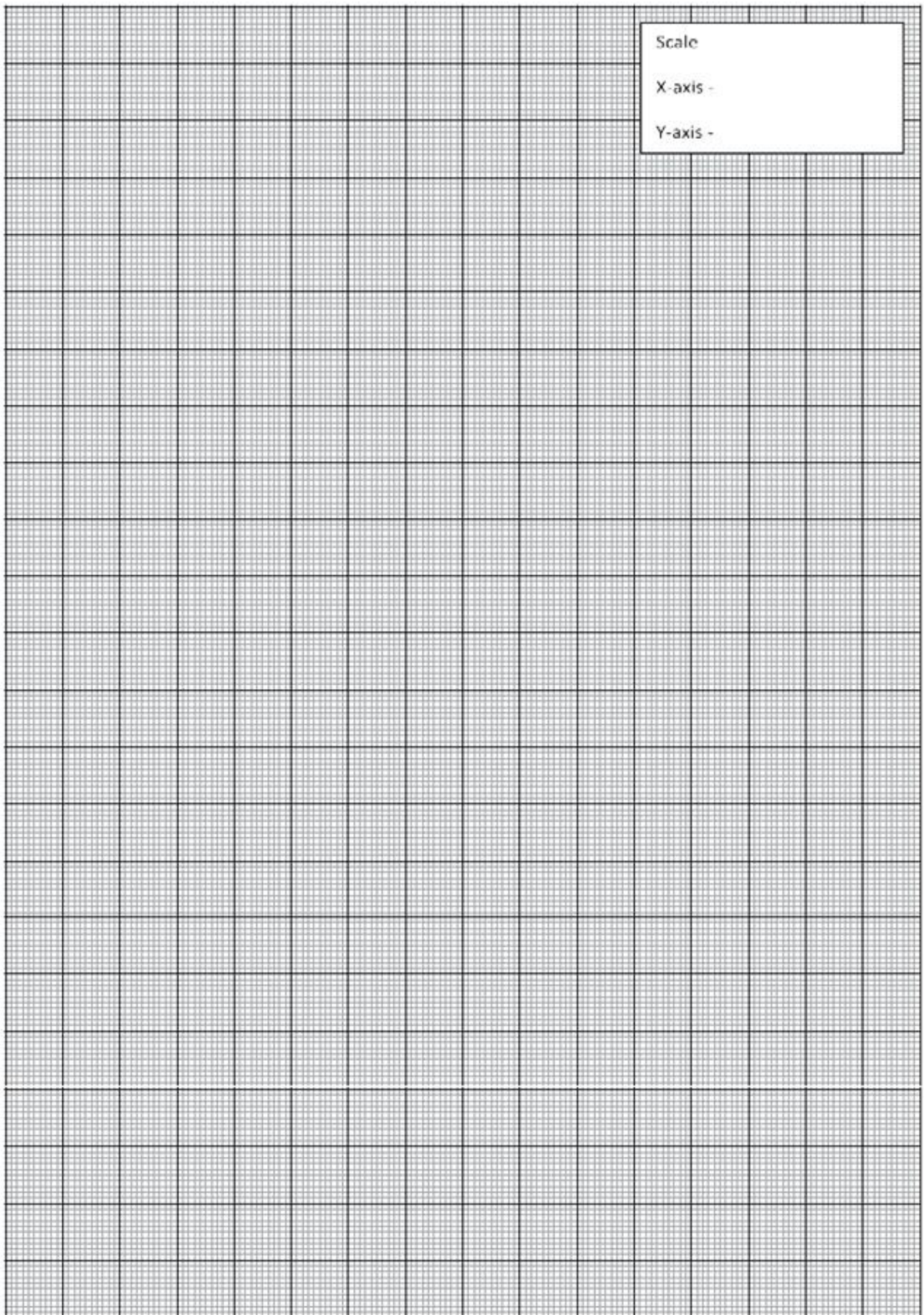
**XVII Assessment Scheme**

<b>Performance indicators</b>		<b>Weightage</b>
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

<b>Marks Obtained</b>			<b>Dated Sign of Teacher</b>
<b>Process Related(15)</b>	<b>Product Related(10)</b>	<b>Total (25)</b>	



**Practical No.15: Use of Solar Panel to drive any small load****I Practical significance:**

Solar panels can be particularly useful in remote or off-grid areas where traditional power sources are impractical or unavailable. The experiment demonstrates the potential for solar energy to provide electricity in such locations, promoting energy access and development. By successfully using solar panels to drive a small load, the experiment demonstrates the feasibility of solar energy applications. This can inspire further research and investment in larger-scale solar projects.

**II Industry / Employer Expected outcome(s)**

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

**III Course Level Learning outcome(s)**

Use specific components for roof top Solar Energy Systems.

**IV Laboratory Learning outcome(s)**

Use a Solar Panel (Small panel approx.- 4.5 V output) to drive any small load.

**V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

**VI Relevant Theoretical Background**

Solar panels operate on the principle of the photovoltaic effect, where certain materials generate an electric current when exposed to sunlight. Photons from sunlight excite electrons in the material, creating an electric potential. This potential can be harnessed to generate electricity. Solar cells are typically made of semiconductors like silicon. Solar panels are usually arranged in groups called arrays or systems. A photovoltaic system consists of one or more solar panels, an inverter that converts DC electricity to alternating current (AC) electricity, and sometimes other components such as controllers, meters, and trackers. Solar panels are used in various industries as per the necessity and requirement.

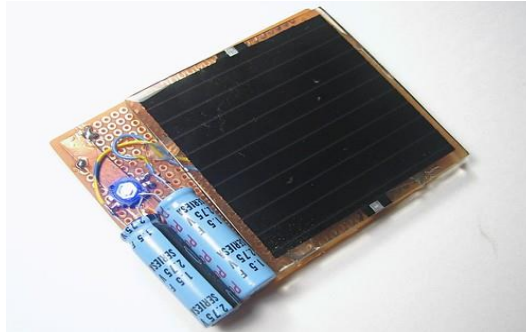


**Figure 15.1: Solar Panel**



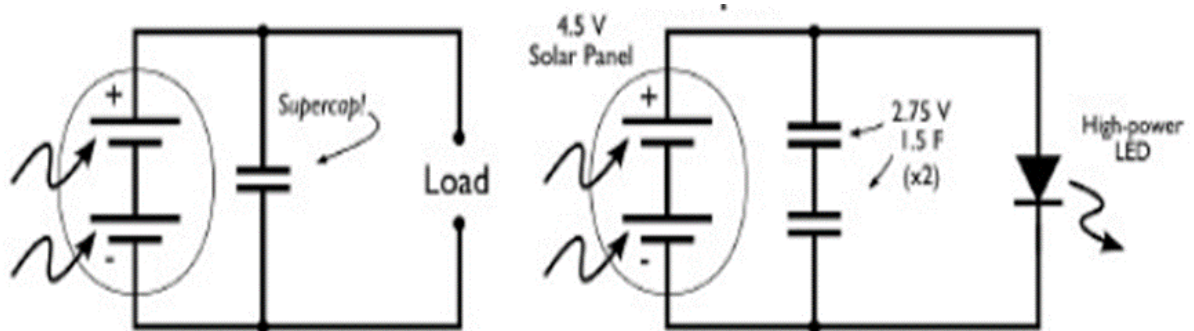
A solar panel can drive a variety of small loads such as -

1. Small DC Motors
2. LED Lights
3. Small Electronic Devices
4. Charging Small Batteries, etc.



**Figure: 15.2 Use of Solar Panel to drive small load (LED circuit)**

**VII Actual Circuit diagram used in laboratory with equipment specifications.**



**Figure 15.3: Circuit diagram**

**VIII Required Resources/apparatus/equipment with specifications.**

Sr. No.	Instrument/Components	Specification	Quantity	Remark
1.	Solar panel cell	output 4.5V	1	
2.	LED	Red/Yellow/Green color 5mm	1	
3.	Capacitor	1.5 F	2	

**IX Precautions to be followed:**

1. Remove any electronic equipment you are doing testing or working on from the power source.
2. Never assume the power circuit is off.
3. Don't connect power to a circuit until you're done working on it and rechecked the work.
4. Always ensure that all electronics equipment are properly grounded.

**X Procedure:**

1. Set up a workspace in a well-lit area or use a controlled light source.
2. Place the solar panel in direct sunlight or under the light source.
3. Ensure all electrical components are in good working condition.
4. Connect the positive (+) and negative (-) terminals of the solar panel to the positive and negative rails on a breadboard.
5. Use connecting wires to link the solar panel to the breadboard securely.
6. Connect the small electrical load (LED bulb, fan or DC motor) to the breadboard.
7. Ensure proper polarity when connecting the load to the breadboard.
8. Check the status of the LED for high light and low light conditions..

**XI Observation table:**

**Table 1: LED driven by Solar panel cell**

Sr. No	Light status	LED Status (ON/OFF)
1	ON (high light on LED)	
2	OFF (No light on LED)	

**XII Result(s)**

.....  
 .....

**XIII Interpretation of results**

.....  
 .....

**XIV Conclusions and recommendation:**

.....  
 .....

**XV Practical related questions**

1. Give examples where direct solar energy is used.
2. Provide examples of small loads that can be effectively powered by solar panels.
3. Name and describe the common types of solar panels.
4. State photovoltaic effect.



**XVI References/Suggestions for further reading: include websites/links**

- 1 <https://www.literoflightusa.org/how-are-solar-panels-made/>
- 2 <https://www.slideshare.net/salmansmd/procedure-sheet-for-the-experiment-solar-cell>
- 3 <https://www.alternative-energy-tutorials.com/photovoltaics/solar-cell-i-v-characteristic.html>

**XVII Assessment Scheme**

<b>Performance indicators</b>		<b>Weightage</b>
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

*Names of Student Team Members*

1. ....
2. ....
3. ....
4. ....

<b>Marks Obtained</b>			<b>Dated Sign of Teacher</b>
<b>Process Related(15)</b>	<b>Product Related(10)</b>	<b>Total (25)</b>	

## **Practical No.16: Voltage and current measurement using series and parallel connection of batteries**

### **I Practical significance:**

Series connection of solar cells is needed to increase the voltage output of the solar panel. By connecting solar cells in series, the voltage of each cell adds up, resulting in a higher total voltage output. This is important for many applications where higher voltage is required, such as charging batteries or connecting to inverters for grid-tied systems.

Parallel connection of solar cells is needed to increase the current output of the solar panel. By connecting solar cells in parallel, the current produced by each cell adds up, resulting in a higher total current output. This is useful in applications where high current is required, such as powering high-current devices or systems with low-voltage but high-current requirements. Additionally, parallel connection helps reduce the impact of shading or mismatch between cells, as each cell operates independently.

### **II Industry / Employer Expected outcome(s)**

The aim of this practical is to help the student to attain the following industry identified outcome through various teaching learning experiences: Use of various Electronic Materials and Components for relevant electronic applications.

### **III Course Level Learning outcome(s)**

Use specific components for roof top Solar Energy Systems.

### **IV Laboratory Learning outcome(s)**

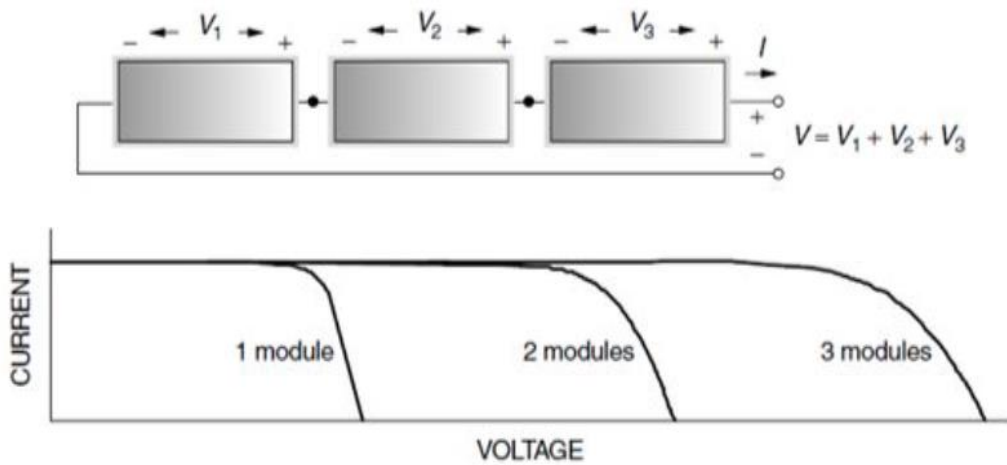
Measure voltage and current by connecting three batteries first in series and then parallel each having rating of 6V, 2A.

### **V Relevant Affective Domain related outcome(s)**

1. Follow safe practices.
2. Handle electronic components and instruments carefully.

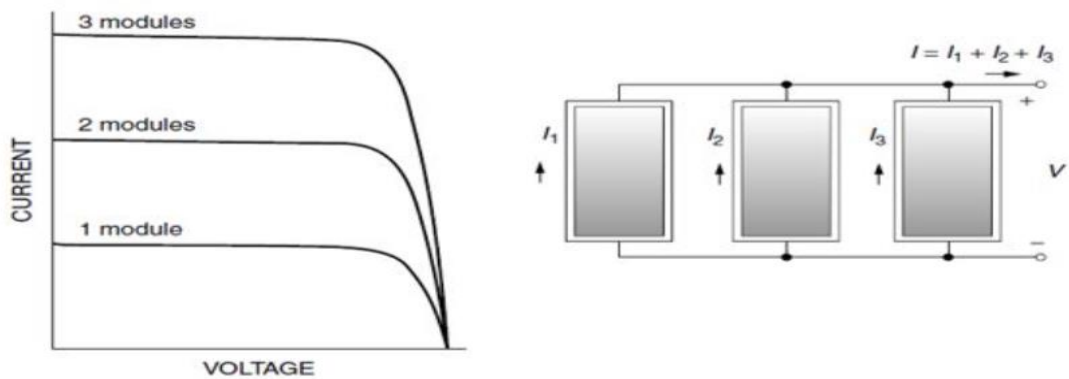
### **VI Relevant Theoretical Background**

Solar cells can be connected in series to increase the output voltage, shown in Figure 16.1. Total voltage is equal to the sum of individual voltages. Solar cells in series are termed **string**. Because solar cells are not perfectly identical, the total current flowing through a string is equal to the lowest value of the solar cell.

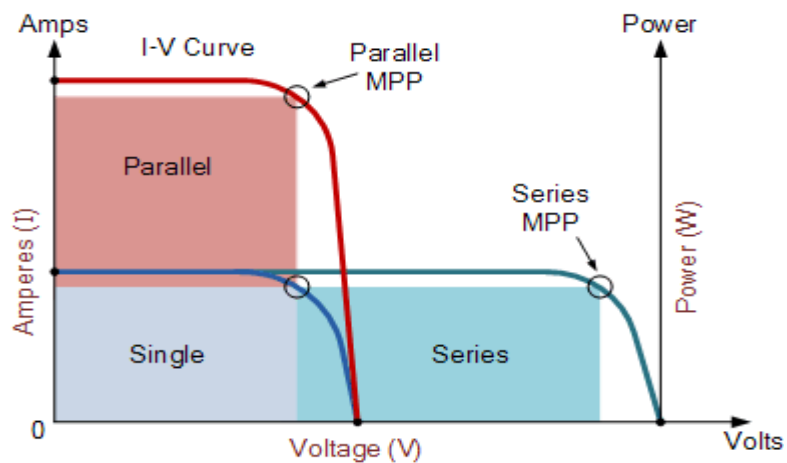


**Figure 16.1 Solar modules in series connection**

Connecting cells in parallel increases the total current, shown in Figure 16.2. Total current is equal to the sum of individual currents.



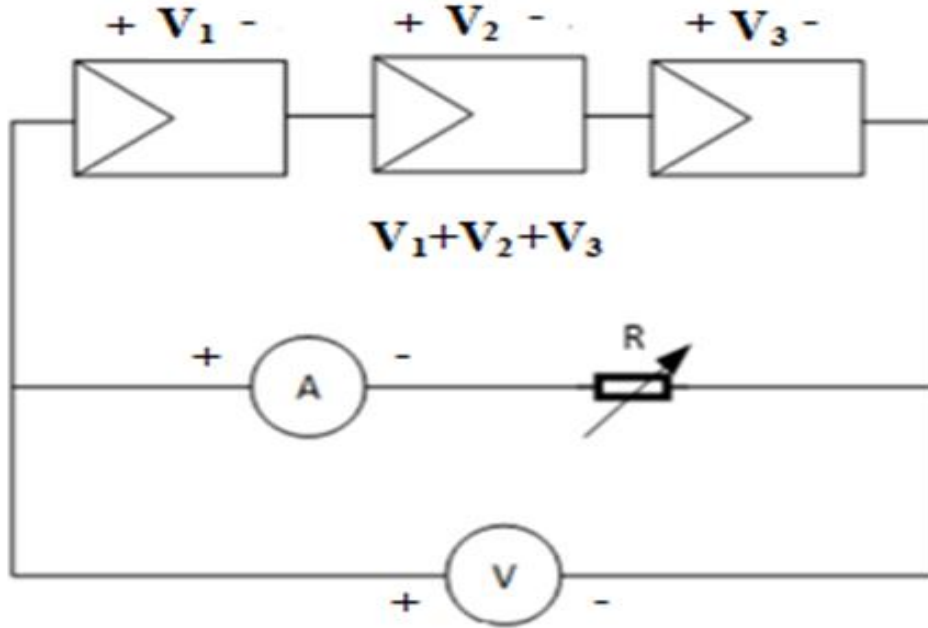
**Figure 16.2 Solar modules in parallel connection**



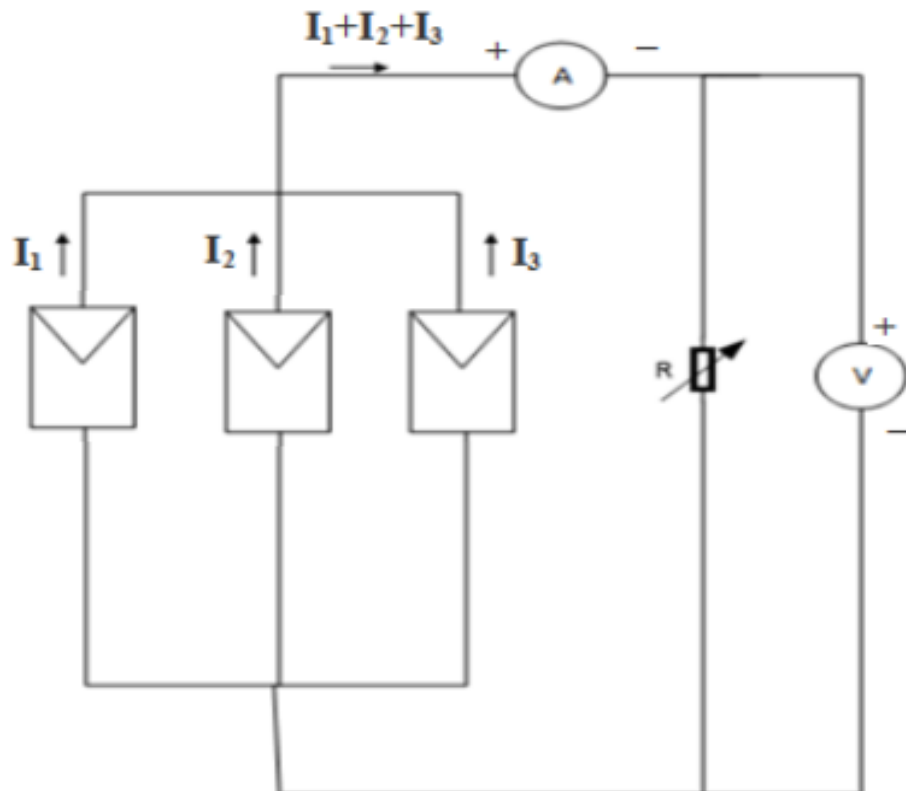
**Figure 16.3 V-I Characteristics of Series and parallel combinations of Solar cell**

By strategically combining solar cells in series, parallel, or a combination of both, PV system designers can tailor the system to meet specific voltage, current, and power requirements for various applications, maximizing the efficiency and effectiveness of the solar power generation system

**VII Actual Circuit diagram used in laboratory with equipment specifications.**



**Figure 16.4 Solar cells in series**



**Figure 16.5 Solar cells in parallel**



**VIII Required Resources/apparatus/equipment with specifications.**

Sr. No.	Instrument /Components	Specification	Quantity	Remark
1	Light Source	Sunlight/Lamp-irradiance 1000W/m <sup>2</sup>	1	
2	Solar Cells	6V, 2A	3	
3	Potentiometer	0-10K $\Omega$	1	
4	Voltmeter	0-100V	1	
5	Current meter	0-100A	1	
6	Connecting wires	0.75 mm <sup>2</sup> cable size	As per requirement	

**IX Precautions to be followed:**

1. Connect voltmeter and ammeter in correct polarities.
2. All electrical connections should be neat and tight.

**X Procedure:****A) Solar Cells - Series Connection**

1. Set the irradiance (Flux of radiant energy) to 1000 W/m<sup>2</sup>
2. Connect three solar cells in series. Measure the open circuit voltage.
3. Connect a potentiometer to the output of the series connection shown in Figure 16.4. Connect the voltage meter in parallel with the solar cells, and the current meter in series to measure the output voltage and current respectively.
4. Vary the value of the potentiometer sequentially according to Table 1 to get a fine curve of IV characteristics. Use the voltmeter and ammeter to measure the output voltage and current with different potentiometer values.
5. Record the voltage and current in Table 1.
6. Record the voltage and current characteristic on the plot (x axis is current, y axis is voltage).
7. Identify the maximum power point on the IV curve.

**B) Solar Cells - Parallel Connection**

1. Set the irradiance (Flux of radiant energy) to 1000 W/m<sup>2</sup>.
2. Connect three solar cells in parallel. Measure the open circuit voltage
3. Connect a potentiometer to the output of the parallel connection shown in Figure 16.5
4. Vary the value of the potentiometer sequentially according to Table 2 to get a fine curve of IV characteristics. Use the voltmeter and ammeter to measure the output voltage and current with different potentiometer values.
5. Record the voltage and current in Table 2.
6. Record the voltage and current characteristic on the plot (x axis is current, y axis is voltage).
7. Identify the maximum power point on the IV curve.

**XI Observation table:****Table 1: Voltage and current measurement for Solar cells in series**

<b>Sr. No</b>	<b>Resistance (<math>\Omega</math>)</b>	<b>Output Voltage (Volt)</b>	<b>Output Current (Ampere)</b>	<b>Output Power (Watts)</b>
1	0.01			
2	0.1			
3	0.3			
4	0.5			
5	1			
6	5			
7	10			
8	100			
9	1K			
10	10K			

**Table 2: Voltage and current measurement for Solar cells in parallel**

<b>Sr. No</b>	<b>Resistance (<math>\Omega</math>)</b>	<b>Output Voltage (Volt)</b>	<b>Output Current (Ampere)</b>	<b>Output Power (Watts)</b>
1	0.01			
2	0.1			
3	0.3			
4	0.5			
5	1			
6	5			
7	10			
8	100			
9	1K			
10	5K			

**A. When solar cells are connected in series**

- 1.  $V_{\text{series}} =$  \_\_\_\_\_
- 2.  $I_{\text{series}} =$  \_\_\_\_\_

**B. When solar cells are connected in parallel**

- 1.  $V_{\text{parallel}} =$  \_\_\_\_\_
- 2.  $I_{\text{parallel}} =$  \_\_\_\_\_

**XII Result(s)**

Observe the plotted graphs and write:

**A. When solar cells are connected in series**

- a. Voltage at Maximum Power Point = \_\_\_\_\_
- b. Current at Maximum Power Point = \_\_\_\_\_
- c. Power at Maximum Power Point = \_\_\_\_\_

**B. When solar cells are connected in parallel**

- a. Voltage at Maximum Power Point = \_\_\_\_\_
- b. Current at Maximum Power Point = \_\_\_\_\_
- c. Power at Maximum Power Point = \_\_\_\_\_

**XIII Interpretation of results**

.....  
.....

**XIV Conclusions and recommendation:**

.....  
.....

**XV Practical related questions**

- 1. List applications of series connection of solar cells.
- 2. List applications of parallel connection of solar cells.
- 3. List advantages of solar cells.
- 4. List disadvantages of solar cells.

**Answers:**

.....  
.....  
.....



**XVI References/Suggestions for further reading: include websites/links**

- 1 <https://renewablelab.niu.edu/experiments/seriesParallelSolarCells>
2. <https://electronics360.globalspec.com/article/18770/understanding-the-series-and-parallel-connection-of-solar-panels>

**XVII Assessment Scheme**

Performance indicators		Weightage
<b>Process related (15 Marks)</b>		<b>60%</b>
1	Handling of the components	10%
2	Identification of component	20%
3	Measuring value using suitable instrument	20%
4	Working in team	10%
<b>Product related (10 Marks)</b>		<b>40%</b>
1	Calculate theoretical values of given component	10%
2	Interpretation of result	05 %
3	Conclusions	05 %
4	Practical related questions	15 %
5	Submitting the journal in time	05%
<b>Total (25 Marks)</b>		<b>100 %</b>

***Names of Student Team Members***

1. ....
2. ....
3. ....
4. ....

Marks Obtained			Dated Sign of Teacher
Process Related(15)	Product Related(10)	Total (25)	

