## PRACTICAL SESSIONS

Practical sessions in B.Tech programs are integral components aimed at complementing theoretical coursework with hands-on experience. These sessions typically take place in laboratories, workshops, or specialized facilities tailored to the specific engineering discipline.

Key aspects of practical sessions in B.Tech include:

1. Application of Theory: Practical sessions enable students to apply theoretical knowledge gained in lectures to real-world scenarios. This hands-on experience helps in understanding complex concepts more effectively.
2. Experimentation and Demonstration: Students conduct experiments, build projects, or work with equipment related to their field of study. This fosters a deeper understanding of principles and methodologies.
3. Skill Development: These sessions help students develop technical skills, such as using specialized software, operating machinery, conducting experiments, and troubleshooting problems.
4. Critical Thinking and Problem-Solving: Through practical sessions, students encounter challenges that require critical thinking and problem-solving skills. They learn to analyze issues and devise solutions, essential skills in engineering practice.
5. Teamwork and Collaboration: Often, practical sessions involve group projects or collaborative work, fostering teamwork, communication, and project management abilities.
6. Industry Relevance: Practical sessions may simulate industry environments, exposing students to tools and techniques used in professional settings, preparing them for future careers.
7. Feedback and Improvement: Instructors provide guidance and feedback, allowing students to refine their skills and understanding based on practical experiences.

Overall, practical sessions in B.Tech programs bridge the gap between theory and application, equipping students with the skills and experience necessary to excel in their respective engineering fields upon graduation.

## LABORATORIES

## 1. Advanced Digital Electronics Lab



## 2.Applied Electronics Lab



## 3.Process Control Instrumentation Lab


4.Industrial Instrumentation Lab


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Principall.VJEC

## 5.Research Lab


6. Project Lab


8.YASKAWA Robotics Lab


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Principal.VJEC
$\qquad$

BRANCH:

ROLL NO:

## Vimal Jyothi ENGINEERING COLLEGE CHEMPERI-KANNUR

## TRANSDUCERS AND MEASUREMENTS LAB

(LAB MANUAL \& WORKBOOK WITH VIVA VOCE)


# TRANSDUCERS AND MEASUREMENTS LAB MANUAL WORKBOOK 

For Second Year B.Tech. Degree Courses<br>(As per the APJ Abdul Kalam Technological University Syllabus)



# Vimal JYothi Engineering College 

JYOTHINAGAR, CHEMPERI, KANNUR-670632
www.vjec.ac.in

Prepared by
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Mrs. Jinsam Mathew
Assistant Professors, E\&I Dept.
Vimal Jyothi Engineering Coldegffature Not Verified
Chemperi

# TRANSDUCERS AND MEASUREMENTS 

## MANUAL AND WORKBOOK

For Second Year B.Tech. Degree Courses<br>(As per the APJ Abdul Kalam Technological University Syllabus)

Name of the Student $\qquad$
Semester\&Branch- $\qquad$
Roll No.
University Reg.No. $\qquad$

## CERTIFICATE

Certified that this is the bonafide record of the work done in the Transducers and Instrumentation Lab of Vimal Jyothi Engineering College Chemperi, Kannur by Mr./Ms. $\qquad$ during the year $\qquad$ .

Date:
Place:

# VIMAL JYOTHI ENGINEERING COLLEGE JYOTHI NAGAR, CHEMPERI, KANNUR DT. 670632 



## MISSION

To prepare the students to see beyond geographical limit and belong to a new age of acquisition and application of technology to meet the challenges of the changing world. Inspired and guided by gospel values, we contribute to the socioeconomic welfare of the country with due concern to the marginalized.

## VISION

To bloom into a Center of Excellence for Technical Education and a pace-setter in rural India with its quality processes and procedures, interwoven with freedom of flexibility, moulding professionals of superior quality, dedicated to the progress and development of humanity.

# VIMAL JYOTHI ENGINEERING COLLEGE 

JYOTHI NAGAR, CHEMPERI, KANNUR DT. 670632


## DEPARTMENT OF

# ELECTRONICS AND INSTRUMENTATION ENGINEERING 

## VISION

The department strives to enrich professionals of high competency in the arena of Instrumentation Engineering \&mould them to adopt the crux of matter in the field of Automation.

## MISSION

To prepare the students to envisage beyond the hypothetical thinking \& belong to a new era of acquisition \& application of Instrumentation Technology to meet the requisition of the changing World.

## PROGRAM EDUCATIONAL OBJECTIVES (PEO)

1. Graduates will achievebroad and in-depth knowledge of Electronics and Instrumentation engineering relating to industrial practices and research to analyze the practical problems and think creatively to generate innovative solutions using appropriate technologies.
2. Graduates will make valid judgment, synthesize information from a range of sources and communicate them in sound ways appropriate to their discipline.
3. Graduates will sustain intellectual curiosity and pursue lifelong learning not only in areas that are relevant to Electronics and Instrumentation engineering, but also that are important to society.
4. Graduates will adapt to different roles and demonstrate leaderships in global working environment by respecting diversity, professionalism and ethical practices.

## PROGRAM OUTCOMES (PO)

Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering application to the solution of complex engineering problems.
2. Problem Analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conditions using first principles of mathematics, natural sciences \& engineering sciences.
3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health \& safety and the cultural, societal and environmental considerations.
4. Conduct investigations of complex problems: Use research based knowledge and research methods including design of experiments, analysis \& interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select \& apply appropriate techniques, resources \& modern engineering \& IT tools including prediction \& modeling to complex engineering activities with an understanding of the limitations.
6. The engineer \& the society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal \& cultural issues \& the consequent responsibilities relevant to the professional engineering practice.
7. Environment \& Sustainability: Understand the impact of the professional engineering solutions in societal \& environmental contexts and demonstrate the knowledge of and need for sustainable development.
8. Ethics: Apply ethical principles \& commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual \& Team work: Function effectively as an individual and as a member or leader in diverse teams and in multi disciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.
11. Project management \& finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one own work, as a member and leader in a team, to manage projects and in multi disciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## PROGRAM SPECIFIC OUTCOME (PSO)

1. Students will have the ability to explore the design, installation \& operation of the basic instrumentation systems used in industrial environments.
2. Students will have a strong foundation in mathematical, scientific \& engineering fundamentals necessary to formulate, solve \& analyze instrumentation problems related to industry \& research.

## Preface

The objective of this manual is to familiarize the students with practical skills, measurement techniques and interpretation of results. It is intended to make this manual self-contained in all respects, so that it can be used as a laboratory manual. In all the experiments, the relevant theory and general guidelines for the procedure to be followed have been given. Tabular sheets for entering the observations have also been provided in each experiment while graph sheets have been included wherever necessary.

It is suggested that the students should complete the computations, in the laboratory itself. However, the students are advised to refer to the relevant text before interpreting the results and writing a permanent discussion and inference. The questions provided at the end of each experiment will reinforce the students understanding of the subject and also help them to prepare for viva-voce exams.

## Author

## Course Objective:

This course aims to
(i) Familiarize the students with various types of sensors and transducers
(ii) Enable students to select and design suitable instruments to meet requirements of various industrial applications

## Course Outcome:

After the completion of the course the student will be able to,

1. Make use of basic transducers for the measurement of physical variables like pressure, temperature etc.
2. Experiment with various measuring instruments and bridges
3. Implement sensor based measurement systems using modern tools

## CO - PO Mapping Table:

| Course | Program Outcomes |  |  |  |  |  |  |  |  |  |  |  | PSO |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\hat{O}$ | N | $0$ | O | O | O | E | $0$ | Ò | $0$ | $\underset{\sim}{7}$ | $\underset{\sim}{2}$ | $\begin{aligned} & \text { O} \\ & 0 \end{aligned}$ | N |
| CO 1 | 3 |  |  |  |  |  |  | 3 | 3 | 2 |  | 1 | 2 | 2 |
| CO 2 | 3 |  | 2 | 1 | 3 |  |  | 3 | 3 | 2 |  | 2 | 2 | 2 |
| CO 3 | 3 |  | 2 | 2 | 3 | 3 |  | 3 | 3 | 2 | 2 | 3 | 2 | 2 |

Level Indicator: 1 - Low 2 - Medium 3 - High

## STUDENTS GUIDELINES

1. Read all the procedures thoroughly before entering the laboratory.
2. Lab coat and shoes should be worn in the laboratory.
3. Studentsare not allowed to work in the laboratory without the presence of the teacher.
4. Don't touch any equipment or other materials in the laboratory area until you are instructed to do so.
5. Labels and equipment instructions must be read carefully before use.
6. If you don't understand how to use a piece of equipment, enquire your teacher.
7. Equipment should not be transferred to any other location without the permission from the laboratory staff.
8. Make sure that the last connections to be made in your circuit is the power supply and first think to be disconnected is also is the power supply.
9. Should request the technician to check the circuit connections before switching on.
10. Keep the bag at the provided place.
11.Take care that hair, clothing and hands are a safe distance from chemicals and the hot plate at all times.
11. Check the label on the chemical bottles twice before removing any of the contents.
13.Don't taste or smell any chemicals.
14.Never return unused chemicals to their original container.
15.Dispose of all the chemical waste properly.
12. Never remove chemicals or other materials from the laboratory area.
17.Don't interfere with the laboratory experiments of others.
13. Work area should be kept clean and tidy at all times.

| AEL 204 | TRANSDUCERS AND | CATEGORY | L | T | P | CREDIT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | MEASUREMENTS LAB | PCC | 0 | 0 | 3 | 2 |

Preamble: This course aims to
(i) Familiarize the students with various types of sensors and transducers
(ii) Enable students to select and design suitable instruments to meet requirements of various industrial applications

## Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

| CO 1 | Make use of basic transducers for the measurement of physical variables like <br> pressure ,temperature etc. |
| :--- | :--- |
| CO 2 | Experiment with various measuring instruments and bridges |
| CO 3 | Implement sensor based measurement systems using modern tools |

Mapping of course outcomes with program outcomes

|  | PO <br> 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO <br> 7 | PO 8 | PO <br> 9 | PO <br> $\mathbf{1 0}$ | PO <br> 11 | PO <br> 12 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| CO 1 | 3 |  |  |  |  |  |  | 3 | 3 | 2 |  | 1 |
| CO 2 | 3 |  | 2 | 1 | 3 |  |  | 3 | 3 | 2 |  | 2 |
| CO 3 | 3 |  | 2 | 2 | 3 | 3 |  | 3 | 3 | 2 | 2 | 3 |

## Assessment

Mark distribution

| Total <br> Marks | CIE | ESE | ESE Duration |
| :--- | :--- | :--- | :--- |
| 150 | 75 | 75 | 2.5 hours |

## Continuous Internal Evaluation Pattern:

Attendance
15 marks
Continuous Assessment
Internal Test (Immediately before the second series test)

End Semester Examination Pattern: The following guidelines should be followed regarding award of marks
(a) Preliminary work : 15Marks
(b) Implementing the work/Conducting the experiment 10Marks
(c) Performance, result and inference (usage of equipments and troubleshooting)
: 25Marks
(d) Viva voice
: 20Sishnature Not Verified
(e) Record

General instructions: End-semester practical examination is to be conducted immediately after the second series test covering entire syllabus given below. Evaluation is to be conducted under the equal responsibility of both the internal and external examiners. The number of candidates evaluated per day should not exceed 20. Students shall be allowed for the examination only on submitting the duly certified record. The external examiner shall endorse the record.

Part A (At least 8 experiments are mandatory)
1 Determination of characteristics optical transducers using LDR
2. Determination of characteristics of LVDT

3 Measurement of strain and load using strain gauge
4. Level measurement using capacitive/resistive transducer

5 Determination of characteristics of RTD
6 Determination of characteristics of thermocouple
7 Determination of characteristics of thermistor
8. Determination of pressure using strain gauge/piezoelectric pickup
9. Determination of sound pressure level using sound level meter
10. Calibration of pressure gauge using dead weight tester

11 Measurement of speed using photoelectric pickup
12 Measurement of speed using stroboscope
13 Determination of characteristics of hall effect transducer
14 Measurement of displacement using inductive transducer
15 Determination of characteristics of capacitive displacement transducer
16. Pressure measurement using U-tube manometer

17 Study of loading effect in potentiometer
18. Measurement of frequency and phase using Lissajous figures

## Part B (At least 4 experiments are mandatory)

Experiments (1-4) shall be done using python/Labview-Aurdino interface

1. Measurement of temperature
2. Measurement of level in water tank
3. Measurement of pressure
4. Wind velocity measurement
5. Measurement of humidity
6. Simulation of Wheatstone bridge using Labview
7. Simulation of Anderson's bridge using Labview
8. Simulation of Maxwell's inductance bridge and Maxwell's inductance capacitance bridge using Labview

## INDEX

| $\begin{aligned} & \text { SL. } \\ & \text { No. } \end{aligned}$ | DATE | EXPERIMENT | PAGE | MARKS OBTAINED |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Continuous Assessment(30) |
| PART A |  |  |  |  |
| 1 |  | DETERMINATION OF THE CHARACTERISTICS OF THERMOCOUPLE | 1 |  |
| 2 |  | DETERMINATION OF THE CHARACTERISTICS OF RTD | 6 |  |
| 3 |  | DETERMINATION OF THE CHARACTERISTICS OPTCAL TRANSDUCER USING LDR | 12 |  |
| 4 |  | DETERMINATION OF THE CHARACTERISTICS OF LVDT | 18 |  |
| 5 |  | MEASUREMENT OF DISPLACEMENT USING INDUCTIVE TRANSDUCER | 25 |  |
| 6 |  | CALIBRATION OF PRESSURE GAUGE USING DEAD WEIGHT PRESSURE GAUGE TESTER | 30 |  |
| 7 |  | LEVEL MEASUREMENT USING CAPACITIVE TRANSDUCER | 36 |  |
| 8 |  | MEASRUEMENT OF SPEED USING MAGNETIC PICKUP TRANSDUCER | 42 |  |
|  |  | PART A |  |  |
| 9 |  | MEASUREMENT OF TEMPERATURE USING LABVIEW-AURDINO INTERFACE | 47 |  |
| 10 |  | MEASUREMENT OF LEVEL USING LABVIEWAURDINO INTERFACE | 61 |  |
| 11 |  | SIMULATION OF WHEATSTONE BRIDGE USING LABVIEW | 68 |  |
| 12 |  | MULATION OF ANDERSON'S BRIDGE USING LABVIEW | 73 |  |
| TOTAL MARKS |  |  |  |  |

## Experiment No: 1

## Date:

## DETERMINATION OF THE CHARACTERISTICS OF THERMOCOUPLE

## Aim: -

To plot the characteristic graph for thermocouple and to find its sensitivity.

## Components and equipments required: -

| SL NO. | COMPONENTS \& EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | Thermocouple | Iron-Constantan | 1 |
| 2. | Thermometer | Mercury in glass <br> type, $0-100^{\circ} \mathrm{C}$ | 1 |
| 3. | Multimeter |  | 1 |
| 4. | Water bath and heater assembly |  | 1 |

## Theory: -

Industrially the most important temperature transducer is the thermocouple. It works on the principle that the contact potential between two dissimilar metals changes with temperature. When two dissimilar metals are joined as in figure with two junctions J1 and J2 at temperatures T 1 and T 2 respectively, then an emf arises, causing a current to flow in the circuit and this effect is known as Seebeck effect.


A difference in temperature between junctions produces a thermal emf which can be measured to calibrate temperature. The simplest measuring system consist of a single apparent junction as shown in figure below. The hot junction $\mathrm{J}_{1}$ is at temperature $\mathrm{T}_{1}$, the connecting wire forms junctions $\mathrm{J}_{2}$ and $\mathrm{J}_{3}$ with thermocouple metals. If both the junctions are at the same temperature $T_{2}$, then emf, $E$ is proportional to $\left(T_{1}-T_{2}\right)$. If both junction temperatures are not same, then emf E has to be found by algebraic addition of the three junction emfs. Temperature $\mathrm{T}_{2}$ with J 2 and J 3 at same value serves as the reference junction temperature.


The relevant laws of thermoelectricity are

1. Law of homogeneous circuit: No current flows in the circuit made of a single metal by the application of heat alone.
2. Law of intermediate metals: If between any two points a number of junctions appear but all at the same temperature, emf between the two points is independent of intermediate metals.
3. Law of intermediate temperatures: Emf for a couple with junction temperature $T_{1}$ and $\mathrm{T}_{3}$ is the sum of two emfs of two couples of same metals having junction temperatures $\mathrm{T}_{1}$ and $\mathrm{T}_{2}$, and $\mathrm{T}_{2}$ and $\mathrm{T}_{3}$ respectively.

In industries, the empirical relation between junction temperature and mV output is given by

$$
\mathrm{E}=\sum_{n=1}^{k}\left(\frac{1}{n}\right) \alpha_{n} t^{n}
$$

In practice $\mathrm{k}=3$ is sufficient.

## Mounting arrangement



## Procedure: -

1. Fill the water bath around $3 / 4^{\text {th }}$ full with water and place the thermocouple and thermometer inside the kettle.
2. Note down the initial water temperature from the thermometer.
3. Connect the thermocouple to multimeter.
4. Switch on the heater and the water starts heating up.
5. Note down the temperature indicated on thermometer and also the corresponding reading on multimeter till the thermometer indicates about $85^{\circ} \mathrm{C}$.
6. Turn off the heater.
7. Plot graph between temperature indicated by thermometer and thermocouple output in mV .
8. Calculate the sensitivity from the slope of the graph plotted for thermocouple output readings.

## Observations

Tabular Column

| Sl.No | Thermometer reading in ${ }^{0} \mathrm{C}$ | Thermocouple Output in mV |
| :--- | :--- | :--- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

## Model graph



Electronics \& Instrumentation Department

## Viva- voce Questions: -

1. What is a thermocouple \& how does it work?
2. List out the advantages of a thermocouple?
3. Write thermoelectric laws of thermocouple?
4. Thermopile is a combination of.
5. Which thermocouple is most commonly used in high temperature applications?

## Calculation: -

## Result:

## Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature Not Verified |  |  |  |  |  |
| Electronics \& Instrumentation Department |  |  |  |  |  |

## Experiment No: 2

## Date:

## DETERMINATION OF THE CHARACTERISTICS OF RTD

## Aim: -

To plot the characteristic graph for RTD and to find its temperature coefficient of resistance.

## Components and equipments required: -

| SL NO. | COMPONENTS \& EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | RTD | Pt 100 | 1 |
| 2. | Thermometer | Mercury in glass <br> type, $0-100^{\circ} \mathrm{C}$ | 1 |
| 3. | Multimeter |  | 1 |
| 4. | Water bath and heater assembly |  | 1 |

## Theory: -

RTDs i.e. Resistance Temperature Detectors work on the principle of change in resistance of metals with change in temperature. The sensor is simply a conductor fabricated as a wire wound coil or as a film or foil grid. The change in resistance of conductor with temperature is given by the expression,
$\mathrm{R}=\mathrm{R}_{0}\left(1+\lambda_{1}\left(\mathrm{~T}-\mathrm{T}_{0}\right)+\lambda_{2}\left(\mathrm{~T}-\mathrm{T}_{0}\right)^{2}+\ldots \ldots \ldots \ldots \ldots \ldots . . . . . . . \lambda_{\mathrm{n}}\left(\mathrm{T}-\mathrm{T}_{0}\right)^{\mathrm{n}}\right)$
Where, $\Delta \mathrm{R}=\left(\mathrm{R}-\mathrm{R}_{0}\right)$
R is the resistance at temperature T
$\mathrm{T}_{0}$ is a reference temperature
$\mathrm{R}_{0}$ is the resistance at temperature $\mathrm{T}_{0}$
$\lambda_{1}, \lambda_{2}, \ldots . \lambda n$ are temperature coefficients of resistance

In narrow ranges of operation only first coefficient is significant, the higher powers of T can be neglected, then the equation becomes
$\mathrm{R}=\mathrm{R}_{0}\left(1+\lambda_{1}\left(\mathrm{~T}-\mathrm{T}_{0}\right)\right)$
The temperature coefficient of resistance $\lambda_{1}$ can be calculated experimentally by statistical means.
Platinum is especially used for the construction of RTD, as it can withstand high temperatures while maintaining excellent stability. As a noble metal, it shows limited susceptibility to contamination. All metals produce a positive change insigesistrae- Not Weithed
temperature. This, of course, is the main function of RTD. The system error is minimized when the normal value of RTD is large. This implies a metal with a high value of resistivity should be used for RTDs. The lower is the resistivity if the metal, the more material will have to use.

## Mounting arrangement



## Procedure: -

1. Fill the water bath around $3 / 4^{\text {th }}$ full with water and place the RTD and thermometer inside it.
2. Note down the initial water temperature from the thermometer.
3. Connect the sensor to multimeter and note ohm meter reading.
4. Switch on the heater and the water starts heating up.
5. Note down the temperature indicated on thermometer and also the corresponding reading till the thermometer indicates about $85^{\circ} \mathrm{C}$.
6. Turn off the heater.
7. Note down the temperature indicated on thermometer and also the corresponding reading till the thermometer temperature drops down to ambient temperature, at the same thermometer readings as tabulated in step 5 .
8. Calculate the mean resistance values as obtained from steps 5 and 7 .
9. Plot graph between temperature indicated by thermometer and resistance for up and down readings as well as for mean resistance values.
10. Calculate the temperature coefficient of resistance from the data tabulated.

## Model graph



## Observations

Tabular Column


## Sample Calculations

$\left(\mathrm{R}-\mathrm{R}_{0}\right) / \mathrm{R}_{0}=\lambda_{1}\left(\mathrm{~T}-\mathrm{T}_{0}\right)$

Thus
$\Sigma\left[\left(\mathrm{R}-\mathrm{R}_{0}\right) / \mathrm{R}_{0}\right]=\lambda_{1} \Sigma\left(\mathrm{~T}-\mathrm{T}_{0}\right)$
Thus,

$$
\lambda_{1}=\Sigma\left[\left(\mathrm{R}-\mathrm{R}_{0}\right) / \mathrm{R}_{0}\right] / \Sigma\left(\mathrm{T}-\mathrm{T}_{0}\right)
$$

## Viva- voce Questions: -

1. Explain the basic principle of RTD?
2. Which metal is commonly used for RTD? What is the reason?
3. What are the major disadvantages of RTD?
4. Write the basic resistance equation of RTD?
5. List the requirements of a conductor material to be used in RTD?

## Calculation: -

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Vimal Jyothi Engineering College |  |  |  |  |  |

## Experiment No: 3

Date:

## DETERMINATION OF THE CHARACTERISTICS OPTCAL TRANSDUCER USING LDR

## Aim: -

1. To perform the calibration of LDR to plot actual reading vs indicated reading.
2. To study and plot characteristics of LDR.

## Components and equipments required: -

| SL NO. | COMPONENTS \& EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | LDR measurement trainer | Input power: $230 \mathrm{~V}, 50 \mathrm{~Hz}$ <br> Variable power supply to <br> bulb: $1 \mathrm{~V}-14 \mathrm{~V}$ | 1 |

## Theory: -

LDR: It is a semiconductor material changing resistance which varying exposure to light. Resistance maximum in dark and get reduced with exposure to light .Variation in resistance proportional to intensity of light.

LDR trainer is an experimental set up to study the characteristics of LDR.LDR is fixed to movable rod inside a tube with a bulb fixed at other end. The intensity of bulb varied by varying excitation voltage to bulb and also by moving LDR rod near or away from bulb. An indicator display distance moved by LDR with respect to bulb. The electronic part consists of small resistance to voltage counter circuit where the op-amp is used for processing.LDR is connected through a resistor to voltage source Vcc and other end to positive input pin, the negative input is connected to mV feeding source to adjust the display to real zero through a variable pot. The input signal is amplified and fed to display unit.

## Circuit Diagram



## Procedure: -

## 1.Calibration

1. Check connections and switch on instrument by rocker switch on front panel so that the display glows.
2. Keep the instrument on for 10 minutes for warm up.
3. Push the LDR shaft full inside till the mark on the shaft coincides the zero on the scale.
4. Increase the voltage to bulb by adjusting VP Spot.
5. Adjust zero pot till display read 0
6. Pull LDR slowly outside for maximum displacement and adjust VPS pot till display reads exact distance moved.
7. Push the LDR inside so that mark coincides zero position and adjust the zero pot till display reads zero once again.
8. Pull LDR slowly in steps of 5 to 10 mm and note corresponding display reading for distance moved.
9. Plot the graph between distances moved vs display reading.

## 2.LDR Characteristics

1. Disconnect the yellow and green terminal near the sensor.
2. Pull the LDR shaft completely outside so that the bulb is away from LDR.
3. Connect the voltmeter to bulb terminal and set it to minimum voltage i.e 1 V to bulb.
4. Connect ohm meter between green and blue terminal and measure resistance of LDR at 1V
5. Increase the voltage to the bulb to 2 V and measure resistance of LDR at 2 V .
6. Note down the readings and tabulate for every 1 V increase in bulb voltage.
7. Tabulate the readings in tabular column and plot the graph of change in resistance of LDR vs voltage given to bulb.

## Model graphs



Electronics \& Instrumentation Department
Signature Not Verified


## Observations

Tabular Column
Measurement of displacement

| Sl. No | Actual displacement(mm) | Indicated reading (mm) |
| :--- | :--- | :--- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |


| Characteristics of LDR |  |  |
| :--- | :--- | :--- |
| SI. No | Voltage to bulb (V) | LDR resistance (K, ) |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Viva- voce Questions:-

1. What is LDR?
2. What are materials used for the LDR?
3. What are applications of LDR?
4. What is the function of LDR?
5. What are two types of light dependent resistor?

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature Not Verified |  |  |  |  |  |

## Experiment No: 4

## Date:

## DETERMINATION OF THE CHARACTERISTICS OF LVDT

## Aim: -

To study the characteristics of an LVDT position sensor with respect to signal conditioned output voltage.

## Components and equipments required: -

| SL <br> NO. |  <br> EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | ITB-12-CE | Operating Temperature $-10^{\circ} \mathrm{C}-55^{\circ} \mathrm{C}$ <br> Cabinet material - Mild steel <br> Accuracy $-0.8 \%$ of full scale division <br> Linearity $-1.67 \%$ of full scale division <br> Dimension $-300 \times 280 \times 90 \mathrm{~mm}$ | 1 |
| 2. | LVDT setup | Excitation Voltage -4 KHz at 2 Vpp <br> Type - Spring Loaded <br> Material - Stainless steel <br> Linearity $-1 \%$ of full scale division <br> Accuracy $-1 \%$ of full scale division | 1 |
| 3. | Multimeter (CRO) |  | 1 |
| 4. | Power Chord |  | 1 |

## Theory: -

LVDT is constructed by connecting an iron core with a non-magnetic rod move freely inside the windings. The iron core is only responsible for flux linkages and the non-magnetic rod does not interface in its action.


The two identical secondary coils have included in them. A sinusoidal voltage of the same frequency as the excitation; however, the amplitude varies with the position of the iron core. When they connect the secondaries in series opposition, a null position at which the net output $\mathrm{e}_{0}$ is essentially zero. Motion of the core from null then causes a larger mutual inductance (coupling) for one coil and a smaller mutual inductance for the other. The amplitude of $\mathrm{e}_{0}$ becomes a nearly linear function of core position for a considerable range on either side of null position.


The voltage $e_{0}$ undergoes a $180^{\circ}$ phase shift in going through null. The output $\mathrm{e}_{0}$ is generally out of the phase with the excitation $e_{e x .}$ however, this varies with the frequency of $e_{\mathrm{ex}}$, and for each differential transformer there exists a particular frequency at which this phase shift is zero. If the differential transformer is used with some readout system that requires a small phase shift between $e_{0}$ and $e_{\text {ex }}$, excitation at the correct frequency can solve this problem. If the output voltage is applied directly to an Ac metre or an oscilloscope, this phase shift is not a problem. The origin of this phase shift can be seen from analysis.

Applying Kirchoff's voltage law,


If the output is an open circuit (no voltage-measuring device attached.
we get that,

$$
i_{p} R_{p}+L_{p} \frac{d i_{p}}{d t}-E_{e x}=0
$$

Now the voltage induced in the secondary coils is given by

$$
\begin{aligned}
& e_{s 1}=M_{1} \frac{d i_{p}}{d t} \\
& e_{s 2}=M_{2} \frac{d i_{p}}{d t}
\end{aligned}
$$

Where $\mathrm{M}_{1}$ and $\mathrm{M}_{2}$ are the respective mutual inductances. Then, the net secondary voltage $\mathrm{e}_{\mathrm{s}}$ is given by,

$$
e_{s}=e_{s 1}-e_{s 2}=\left(M_{1}-M_{2}\right) \frac{d i_{p}}{d t}
$$

For a fixed core position the net mutual inductance (M1-M2) is the quantity that varies linearly with core motion.

## Front Panel Diagram



## Procedure:-

1. Install the LVDT position sensor and interface the 9 pin D connector with ITB-12-CE.
2. Switch ON the unit.
3. Connect the multimeter or CRO (in DC-Volt mode) across T6 and T7 for signal conditioned output voltage measurement.
4. Adjust the micrometer to 10 mm displacement and tune the zero adjustment POT to zero mm displacement on display. The voltage across the T6 and T7 should be zero volts.
5. Adjust the micrometer to 20 mm displacement and tune the gain adjustment POT to 10 mm on the display. The voltage across the T6 and T7 should be 5 V .
6. Repeat the zero and span calibration until the core displacement is 0.00 mm for 10 mm displacement in micrometer and 10.00 mm for 20 mm displacement in thesmicrometer ${ }_{\text {verified }}$
7. After completion of the calibration, give the displacement from the micrometer to the core of the LVDT sensor.
8. Gradually increase the micrometer displacement from 10 mm to 20 mm and note down the forward core displacement from zero mm to 10 mm on the display and signal conditioned output voltage (V) across T6 and T7.
9. Similarly, decrease the Micrometer displacement from 10 mm to zero mm and note down the reverse core displacement of zero to -10 mm on the display and signal conditioned output voltage (V) across T6 and T7.
10. Tabulate the readings of the core displacement, Micrometer displacement and signal conditioned output voltage (V).
11. Plot the graph between core displacement (mm) along x -axis and the signal conditioned output voltage (V) along y-axis.

## Observations

Tabular Column

| Sl.No | Micrometer <br> displacement <br> $(\mathrm{mm})$ | Core displacement <br> $(\mathrm{mm})$ | Signal conditioned <br> Output voltage <br> (volt) |
| :--- | :--- | :--- | :--- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Model graph



## Viva- voce Questions:-

1. What is LVDT?
2. What are the advantages of LVDT?
3. What are the applications of LVDT?
4. List basic components of LVDT?
5. What is the value of operating frequency \& excitation voltage?

## Result:

## Evaluation of Experiment:-

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature Not Verified |  |  |  |  |  |

## Experiment No: 5

## Date:

## MEASUREMENT OF DISPLACEMENT USING INDUCTIVE TRANSDUCER

## Aim: -

To measure and calibrate the inductive transducer and plot graphs between indicated reading and actual reading, error and actual reading and also to find out percentage error and accuracy.

## Components and equipments required: -

| SL NO. | COMPONENTS <br> \& EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | Sensor: Wire wound on an acrylic bobbin in <br> which a soft iron core moves inside. <br> Measuring variable: Displacement 0-20mm <br> max. <br> Excitation voltage: 1Vpp at 1 KHz <br> Display: 3.5 digit LED display to read up to <br> $+/-1999$ at +/-200mV FSD <br> Zero and calibration: Single turn <br> potentiometers <br> Power: $230 \mathrm{~V}, 50 \mathrm{~Hz}$ | 1 |  |
| Inductance <br> measurement <br> trainer assembly |  |  |  |

## Theory: -

The variable inductance transducer work generally upon one of the following three principles.

1. Change of self-inductance.
2. Change of mutual inductance.
3. Product of eddy current.

The self-inductance of the coil $\mathrm{L}=\frac{N^{2}}{R}$
Where, $\mathrm{N}=$ number of turns, and $\mathrm{R}=$ reluctance of the magnetic circuit.
The reluctance if the magnetic circuit $\mathrm{R}=\frac{L}{\mu A}$
$\therefore$ Inductance $\mathrm{L}=\mathrm{N}^{2} \mu\left(\frac{A}{l}\right)=\mathrm{N}^{2} \mu \mathrm{G}$
Where
$\mu=$ effective permeability of the medium in and around the coil; $\mathrm{H} / \mathrm{m}$,
$\mathrm{G}=A / l=$ geometric form factor,
$\mathrm{A}=$ area of cross-section of coil; $\mathrm{m}^{2}$
$l=$ length of coil; m
It is clear from equation (1) that the variation in inductance may be caused by:
(i) Change in number of turns, N ,
(ii) Change in geometric configuration, G,
(iii) Change in permeability, $\mu$,

Inductance transducers are mainly used for measurement of displacement. The displacement to be measured in arranged to cause variation of any of three variables in equation (1) and thus alter the self- inductance $l$ by $\Delta l$.

Measurement of displacement using inductance coil by varying self-inductance can be made by connecting Inductance Bridge in the form of Wheatstone bridge called Inductance Bridge, which has an additional advantage that it is self-balancing. The output of the inductance bridge will vary linearly as the core moves inside the coil. The ac output is rectified and calibrated to read displacement of soft iron.

## Procedure: -

1. Make the connections correctly.
2. Switch on the connections.
3. Keep the instrument on for 10 minutes to warm up.
4. Move the core so that the end of core touches zero position on the scale. At this position display reads " 000 ".
5. Move the core slowly in steps of 5 mm , the display starts showing displacement in mm . tabulate readings.

## Circuit Diagram



## Model graph



Actual Reading (mm)

## Observations

Tabular Column

| Sl. No | Actual <br> Displacement(mm) | Indicated Reading <br> $(\mathrm{mm})$ | Error | \%Error |
| :--- | :--- | :--- | :--- | :--- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

## Sample Calculations

Error $=$ Actual reading - Indicated reading
\%Error $=\left[\right.$ (Actual reading - Indicated reading)/ Actual reading] ${ }^{*} 100$
Mean \%Error= $\underline{\underline{\sum E r r o r}}$
No. of Readings
Accuracy in \% = $100-$ Mean \%Error

## Viva- voce Questions: -

1. List out the different types of inductive transducers?
2. What are the applications of inductive transducer?
3. Write the advantages of inductive transducer?
4. Explain the differential output configuration of inductive transducer?
5. Write the transducers working principle of production of eddy currents?

## Calculation: -

## Result:

## Evaluation of Experiment: -

| SCORING CRITERIA | NO PERFORMANCE 0 | $\begin{gathered} \text { AVERAGE } \\ 0.5 \end{gathered}$ | $\begin{gathered} \text { SATISFACTORY } \\ 1 \end{gathered}$ | $\begin{gathered} \text { GOOD } \\ 5 \end{gathered}$ | $\begin{gathered} \text { EXCELLENT } \\ 7.5 \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Punctuality \& Timely Completion |  |  |  |  |  |
| Basic knowledge(VIVA) |  |  |  |  |  |
| Overall Performance (Conduct of experiment / Procedure \& |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature Not Veritied |  |  |  |  |  |

## Experiment No: 6

## Date:

## CALIBRATION OF PRESSURE GAUGE USING DEAD WEIGHT PRESSURE GAUGE TESTER

Aim: -
To calibrate pressure gauge using dead weight pressure gauge tester.
Components and equipments required: -

| SL <br> NO. |  <br> EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | Dead weight pressure gauge <br> tester | Range: $0.4 \mathrm{kgf} / \mathrm{cm}^{2}-25 \mathrm{kgf} / \mathrm{cm}^{2}$ | 1 |
| 2. | Standard weights | $0.1 \mathrm{~kg}, 0.4 \mathrm{~kg}, 0.5 \mathrm{~kg}, 1 \mathrm{~kg}(2)$ | 5 |
| 3. | Pressure gauge | Range: <br> $0.4 \mathrm{kgf} / \mathrm{cm}^{2}-25 \mathrm{kgf} / \mathrm{cm}^{2}$ | 1 |
| 4 | Oil | SAE $30 / 40$ |  |

## Theory: -

The dead weight pressure gauge tester works on the principle of pascal's law which states that pressure exerted at a point in chamber filled with liquid is equally transmitted to all the points in the chamber. In the dead weight tester oil is filled in closed chamber with arrangement to exert force through a piston of area known with high accuracy. Force is exerted by placing weights of high accuracy on this piston. The resulting pressure developed in the chamber can be calculated by dividing the weight exerted by weights by area of the piston. The pressure so calculated may be marked on the weights placed. If a pressure gauge is placed in this system, it should indicate the same pressure as that calculated from weights placed on the piston. The liquid used should be (under ambient temperature conditions) viscous enough to prevent penetration in the moving gap of piston and also not that viscous to cause sluggish movement of piston.

## Procedure: -

1. Place a spirit level on the weight carrier and level the instrument by means of the leveling screws and lock the leveling screws by tightening lock nuts provided
2. After the leveling the instrument, fully close the release valve and pour the SAE 30/40 oil to $2 / 3^{\text {rd }}$ of the capacity of the reservoir.
3. Mount the pressure gauge to be tested using appropriate connectors and washer to avoid the air leakage.
4. Now fully open the release valve and gauge valve.
5. Turn screw pump handle clockwise fully. This will expel some air from the system which will bubble out in the oil cup. Turn the handle anticlockwise fully to draw-in oil in to the instrument. Repeat clockwise/anticlockwise turning of the handle a number of times until no bubbles appear in the oil cup.
6. Draw-in oil fully and close the release valve.
7. Check if the pointer position corresponds to 0 reading when no pressure is applied. If a non-zero value is shown, then remove the pointer and refix it to give zero reading.
8. Place the necessary weight (or weights) on the carrier so that the sum of the pressure values of the carrier and weights loaded is equal to the first reading to be taken.
9. Slowly turn screw pump clockwise. This will build-up pressure in the circuit and after a few turns will show on the pressure gauge. Rotate the weights on carrier by hand to reduce the effect of friction in the free piston.
10. Continue to increase the pressure and also to rotate the weights until the piston with weights rises up.
11. Watch the top of the piston, where the red band region is seen. The piston can rise a little more before the internal lock stops further movement. The piston is free from constraint and is floating on the oil pressure if (i) it has risen, (ii) is anywhere within the red band region and (iii) is rotating as explained above, but after reaching the internal lock it is not floating freely.
12. Tap the gauge by a finger to eliminate the friction in the gauge mechanism and take the reading on it. Write it down against the sum of the carrier and the weights loaded.
13. Apply load corresponding to maximum gauge reading and adjust span screw to obtain correct reading.
14. Unload the weights.
15. Progressively load weights in the desired step on the weight carrier and take the reading at each point in the same manner as the first reading.
16. After the maximum reading has been taken, the readings for decreasing pressure at the same points as before. Consider mean value at each reading point.
17. Plot the graph between mean gauge reading and readings given by weights

## Mounting arrangement




## Model graph



## Observations

Tabular Column

| Sl. No | Deadweight <br> $\left(\mathrm{kg} / \mathrm{cm}^{2}\right)$ | Pressure gauge Reading(kg/cm²) |  |  | Error in\% |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  |  | Ascending | Descending | Mean |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

## Sample Calculations

Error $=$ Actual reading - Indicated reading
\%Error $=[($ Actual reading - Indicated reading $) /$ Actual reading $] * 100$

## Viva- voce Questions: -

1. Explain the basic operating principle of deadweight tester?
2. What are the application advantages of deadweight tester?
3. Define calibration?
4. Why dead weight tester called dead weight tester?
5. What are the correction factors incorporated with dead weight tester?

## Calculation: -

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO PERFORMANCE 0 | $\begin{gathered} \text { AVERAGE } \\ 0.5 \end{gathered}$ | $\begin{gathered} \text { SATISFACTORY } \\ 1 \end{gathered}$ | $\begin{gathered} \text { GOOD } \\ 5 \end{gathered}$ | $\begin{gathered} \text { EXCELLENT } \\ 7.5 \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Punctuality \& Timely Completion |  |  |  |  |  |
| Basic knowledge(VIVA) |  |  |  |  |  |
| Overall Performance (Conduct of experiment / Procedure \& Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) | Signature Not Verified |  |  |  |  |

## Experiment No: 7

## Date:

## LEVEL MEASUREMENT USING CAPACITIVE TRANSDUCER

## Aim: -

To measure the liquid level in the process tank using capacitive level transmitter and to the capacitive transmitter output current characteristics against actual level in the tank.

Components and equipments required: -

| SL <br> NO. |  <br> EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | Level transmitter | Sensor: Capacitive <br> Excitation: 24V DC <br> Output: 4-20 mA <br> Accuracy: 5\% | 1 |
| 2. | Measuring tank | Height: 55cm | 1 |
| 3. | Electronics module with <br> LED display assembly to <br> convert 4-20mA from <br> transmitter to digital <br> display in cm | Display: 3.5 digit seven <br> segment LED <br> Zero adjustment: <br> Potentiometer <br> Calibration: Potentiometer | 1 |
| 4. | Pump | Motor: Fractional Horse <br> Power(FHP) motor. <br> Pump type: Submersible | 1 |
| 5. | Multimeter |  | 1 |

## Theory: -

Capacitive level transmitter considered here is a device which varies its current output from 4 to 20 mA for a change in level from $0 \%$ to $100 \%$ respectively, transmitter with inverse response can also be designed. The change in output current based on change in level is implemented by an electronic circuit which varies the output current depending on the change in capacitance of a system acting like a variable capacitor with value of capacitance varying with change in level. In the experimental setup under consideration the capacitive system is formed by two vertical electrodes extending from bottom to top of process tank. The two electrodes act like parallel plates of a capacitor. When water is at the bottom level the space between electrodes is filled with air, but as the level increases the space becomes increasingly filled with water, causing a change in dielectric constant of medium between the capacitive electrode depending on level.

As the relation between capacitance C and dielectric constant $\varepsilon$ in a parallel plate capacitor with area of plates A and distance of separation d is given by

$$
C=(\varepsilon A) / d
$$

In a system where $\varepsilon$ varies with level capacitance $C$ also varies with level and this change in capacitance is converted to change in current in the range of $4-20 \mathrm{~mA}$. This $4-20 \mathrm{~mA}$ is again converted in to voltage and fed in to an ADC and then fed to a digital LED supply to give display in terms of level.

## Mounting arrangement



## Procedure: -

1. Fill the storage tank with water till half the capacity.
2. Check whether the drain valve is in closed position or not, if not close it.
3. Connect the three pin cable provided at the back of the instrument to 230 V supply.
4. Switch on the instrument by ON/OFF switch on the front panel of the instrument.
5. The display glows to indicate that instrument is on. Connect the multimeter to $4-20 \mathrm{~mA}$ output terminal at the back panel to read the current output, initially it is shorted, if we need to measure $4-20 \mathrm{~mA}$ output remove the short and connect it to the multimeter to measure the output. Short the $4-20 \mathrm{~mA}$ display at the back, if the reading is to be taken from digital display on front panel, as in unshorted condition the display do not show the readings.
6. Ensure that the initial level of the water tank is 0 cms , the multimeter reads 4 mA . Adjust the zero potentiometer on the front panel, so that the display reads " 000.0 "
7. Switch on the motor, the water level starts increasing inside the measuring tank. Let the water level reach the maximum position $(50 \mathrm{cms})$. Switch off the motor. The display should show the maximum level in cms as 50 cms . If any change, adjusts the calibration potentiometer on the panel to make the display read 50 cms .
8. Release the drain valve till the water level decreases by 5 cms and note down the reading on digital display and corresponding level reading on the vertical scale provided with transparent process tank. Repeat this for every 5 cm decrease in level, till the water level reaches 0 cm . Tabulate the readings in a tabular column.

## Model graph



## Observations

Tabular Column

| Sl. <br> No | Actual level (cm) | Indicated level (cm) | Level transmitter <br> output in mA | Error |
| :--- | :--- | :--- | :--- | :--- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

## Sample Calculations

Error $=$ Actual reading - Indicated reading

## Viva- voce Questions: -

1. Define capacitance?
2. What parameters are changed to change capacitor?
3. As the level increases, what happens of capacitance?
4. Capacitive type transducer is used for measurement of solids or liquids or both?
5. List advantages of capacitive transducer?
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## Calculation: -

## Result: -

Evaluation of Experiment: -
$\left.\begin{array}{|c|c|c|c|c|c|}\hline \text { SCORING CRITERIA } & \begin{array}{c}\text { NO } \\ \text { PERFORMANCE } \\ 0\end{array} & \begin{array}{c}\text { AVERAGE } \\ 0.5\end{array} & \begin{array}{c}\text { SATISFACTORY } \\ \mathbf{1}\end{array} & \begin{array}{c}\text { GOOD } \\ 5\end{array} & \begin{array}{c}\text { EXCELLENT } \\ 7.5\end{array} \\ \hline \begin{array}{c}\text { Punctuality \& } \\ \text { Timely Completion }\end{array} & & & & \\ \hline \begin{array}{c}\text { Basic } \\ \text { knowledge(VIVA) }\end{array} & & & & \\ \hline \begin{array}{c}\text { Overall Performance } \\ \text { Conduct of experiment } \\ \text { /Procedure \& } \\ \text { Observations) }\end{array} & & & \\ \hline \text { Result } & & & \\ \hline \text { Total Marks(30) } & & & \\ \hline \text { Signature Not Verified }\end{array}\right]$

## Experiment No: 8

## Date:

## MEASRUEMENT OF SPEED USING MAGNETIC PICKUP TRANSDUCER

## Aim: -

To measure speed using stroboscope and to plot the characteristic graph between actual and indicated reading.
Components and equipments required: -

| SL <br> NO. |  <br> EQUIPMENTS | SPECIFICATION | QUANTITY |
| :--- | :--- | :--- | :--- |
| 1. | Speed measurement <br> assembly | Sensor: <br> 1. Magnetic pick up <br> 2. Photoelectric sensor <br> Motor: FHP DC motor to rotate at 1500 <br> rpm (max) <br> Tone wheel: <br> 1. Magnetic pickup: MS wheel 2mm <br> thick disk, with 60 equidistant <br> teeth on the circumference. | 1 |
| 2. | Stroboscope | 2. Photoelectric pick up: A small <br> copper disk with 60 equidistant <br> slots on etched along <br> circumference | Power: 230V,50Hz |

## Theory: -

Stroboscope produces light flashes at different frequencies till a pattern on the rotating wheel appears stationary to the observer. The frequency at which the pattern appears stationary can be used to calculate the rotating speed of rotor.

A magnetic pick up senses periodic changes in reluctance as the rotor teeth of rotating tone wheel moves towards and away from the magnetic sensor. This result in pulses which are counted by a counter and the number of pulses in a given interval gives a measurement of the speed of rotation, which is measured and displayed by an associated electronic circuit.

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| :---: | :---: |
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Mounting arrangement


## Procedure: -

1. Check the connections.
2. Switch on the instrument by pushing down toggle switch on rear side of box, so that LED glows to indicate on state.
3. Keep instrument on for 10 minutes for warm up.
4. Select the sensor with the help of toggle switch.
5. Vary speed by electronic regulator the display will start indicating exact rpm of the motor. Tabulate the reading
6. Adjust flash frequency in stroboscope such that rectangular patch on tone wheel appears stationary. Stroboscope display rpm value corresponding to the flash rate.
7. Tabulate the reading.

## Model graph



Actual Reading (rpm)

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## Observations

Tabular Column

| SI.No | Actual Speed(rpm) | Indicated Speed(rpm) | Error | \%Error |
| :--- | :--- | :--- | :--- | :--- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

## Sample Calculations

Error $=$ Actual reading - Indicated reading
\%Error $=[($ Actual reading - Indicated reading $) /$ Actual reading $] * 100$

## Viva- voce Questions: -

1. What is the instrument used for measurement of speed?
2. Name the instrument user to measure angular velocity?
3. List the advantages and disadvantages of stroboscopic method?
4. Explain the basic principle of photoelectric tachometer?
5. Define tachometer?

## Calculations

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature Not Verified |  |  |  |  |  |

## Experiment No: 9

## Date:

## MEASUREMENT OF TEMPERATURE USING LabVIEW-ARDUINO INTERFACE


#### Abstract

Aim: - To display the temperature measured using RTD on a PC screen with LabVIEW software interfaced with Arduino.


## Components and equipments required: -

RTD, Aurdino board, LabVIEW software abd PC

## Theory: -

RTD is a resistance temperature detector.
It is a metallic resistive element that changes its resistance with temperature according to the eqn,
$R_{t}=R_{0}(1+\alpha . \Delta t)$ where $\alpha$ is positive temperature coefficient. $R_{t}, R_{0}$ is the resistance at temperature $\mathrm{t}^{\mathrm{O}} \mathrm{C}$ and $0^{\circ} \mathrm{C}$ respectively. $\Delta \mathrm{t}$ is the change in temperature. The choice of RTDs are governed by high temperature coefficient high sensitivity, linearity of resistance, stability of electrical characteristics to contamination, sufficient mechanical strength etc.

Many RTD elements consist of a length of fine wire wrapped around a ceramic or glass core but other constructions are also used. The RTD wire is a pure material, typically platinum, nickel, or copper. The material has an accurate resistance/temperature relationship which is used to provide an indication of temperature. As RTD elements are fragile, they are often housed in protective probes. RTDs, which have higher accuracy and repeatability, are slowly replacing thermocouples in industrial applications below


## Construction of RTD



## Diagram:-



## Arrange water bath



## RTD to Arduino Connection

## Procedure: -

1. Arrange waterbath to be heated and monitored for temperature with an RTD
2. Connect RTD to Arduino
3. Interface Arduino with LabVIEW using Digilent LINX

It requires installation of Digilent LINX using VI package manager.

|  | Signature Not Verified |
| :---: | :---: |
| Electronics \& Instrumentation Department | Principall YJEC <br> Vimal Jyothi Engineering College |

```
VI JKI VIPM - Digilent LINX (Control Arduino, Raspberry Pi, BeagleBone and more)
X
File Help
```

Package Information
Select an action to perform on the package.


After installation create a new VI say TemperatureMonitor.vi and go to `Tools>>MakerHub>>LINX>>LINXFirmwareWizard
Electronics \& Instrumentation Department $\quad$ Vimal Jyothi Engine Pringature Not Verified


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Change device type to ArduinoUno


Click Next and select the com port to which Arduino Uno is connected in this case com7




LINX Firmware Wizard


Firmware Version
LINX - Serial / USB


LINX firmware for the Arduino Uno with Serial/USB interface enabled.

## Upload Type

Pre-Built Firmware
$\square$

$x$ Cancel


Right click on block diagram window and select as below.



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## Block Diagram



## Front Panel



## Viva- voce Questions: -

1. What is LabView?
2. List out the Features of Labview
3. How can we interface an Aurdino with LabVIEW
4. List out the characteristics of RTD
5. What is Arduino

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> $\mathbf{1}$ | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of <br> experiment / <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  | Vimal Jyothi Engineering College |  |  |  |

## Experiment No: 10

## Date:

## MEASUREMENT OF LEVEL USING LabVIEW- ARDUINO INTERFACE

## Aim: -

To display the level measured using Bubbler type level transmitter on a PC screen with LabVIEW software interfaced with Arduino.

## Components and equipments required: -

Bubbler type level transmitter, Aurdino Board, LabVIEW software, PC

## Theory: -

In the bubble type level system, liquid level is determined by measuring the pressure required to force a gas into a liquid at a point beneath the surface.

This method uses a source of clean air or gas and is connected through a restriction to a bubble tube immersed at a fixed depth into the vessel. The restriction reduces the airflow to a very small amount. As the pressure builds, bubbles are released from the end of the bubble tube.

Pressure is maintained as air bubbles escape through the liquid. Changes in the liquid level cause the air pressure in the bubble tube to vary. At the top of the bubble tube is where a pressure sensor detects differences in pressure as the level changes.

Most tubes use a small V-notch at the bottom to assist with the release of a constant stream of bubbles. This is preferable for consistent measurement rather than intermittent large bubbles.


The Bubbler System is an inexpensive but accurate means of measuring the fluid level in open or vented containers, especially those in harsh environments such as cooling tower sumps, swimming pools, reservoirs, vented fuel tanks, drain sumps, air washers, etc. The system consists of a source of compressed air, air flow restrictor, sensing tube and pressure transmitter. The only component of the Bubbler System that is exposed to the elements is the sensing tube. All other components can be remotely located in a protected area.

The sense tube is installed in the tank and connected to the pressure transmitter and the air supply through the flow restrictor as shown in Figure. Since the pressure required to displace the liquid is determined by the depth of the fluid, the transmitter output indicates the fluid depth above the open end of the sense tube.

Note that it is not necessary to extend the sense tube to the bottom of the container if you are only interested in the fluid height in the top part of the container. Using a shorter sense tube and lower range pressure transmitter, will improve the resolution and accuracy of the system.

It may be necessary to install a check valve at the high point in the air line if the fluid level is above the air supply and pressure transmitter. This may prevent siphoning of the fluid back to the transmitter and air compressor, if there is a power failure.

## Diagram:-



Level Transmitter to Arduino connection


## Procedure: -

1. Connect Level Transmitter to Arduino
2. Interface Arduino with LabVIEW using Digilent LINX.

It requires installation of Digilent LINX using VI package manager.

## FRONT PANEL



## BLOCK DIAGRAM



## Viva- voce Questions: -

1. Which are the two parts of Aurdino?
2. What are the two panels used in LabVIEW programming?
3. What Are The Advantages Of Labview?
4. What is level transmitter?
5. How does a bubbler level transmitter work?

## Result:

Evaluation of Experiment: -

| SCORING <br> CRITERIA | NO <br> PERFORMANC <br> E | AVERAGE <br> 0.5 | SATISFACTOR <br> $\mathbf{Y}$ <br> 1 | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely <br> Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall <br> Performance <br> (Conduct of <br> experiment / <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |
| Signature No Verified |  |  |  |  |  |

## Experiment No: 11

## Date:

## SIMULATION OF WHEATSTONE BRIDGE USING LabVIEW

## Aim: -

To simulate the operation of a Wheatstone bridge using LabVIEW.

## Components and equipments required: -

LabVIEW software, PC

## Theory: -

The Wheatstone Bridge diamond shaped circuit who's concept was developed by Charles Wheatstone can be used to accurately measure unknown resistance values, or as a means of calibrating measuring instruments, voltmeters, ammeters, etc, by the use of a variable resistance and a simple mathematical formula.

Although today digital multimeters provide the simplest way to measure a resistance, the Wheatstone Bridge can be used to compare an unknown resistance to that of a known resistance to determine its value allowing very low values of resistances down in the milliohms $(\mathrm{m} \Omega)$ range to be measured.

The Wheatstone bridge (or resistance bridge) circuit can be used in a number of applications and today, with modern operational amplifiers one can use the Wheatstone Bridge Circuit to interface various transducers and sensors to these amplifier circuits.

The Wheatstone Bridge circuit is nothing more than two simple series-parallel arrangements of resistances connected between a voltage supply terminal and ground producing zero voltage difference between the two parallel branches when balanced. A Wheatstone bridge circuit has two input terminals and two output terminals consisting of four resistors configured in a familiar diamond-like arrangement as shown.
This is typical of how the Wheatstone bridge is drawn.

## The Wheatstone Bridge



When balanced, the Wheatstone bridge can be analyzed simply as two series strings in parallel. Each resistor within the series chain produces an IR drop, or voltage drop across itself as a consequence of the current flowing through it as defined by Ohms Law.

## Diagram:-



Procedure: -

1. Create a VI in LabVIEW with the following front panel and block diagram.

## FRONT PANEL



## BLOCK DIAGRAM


2. Set the value of variable resistor Rx to a random value and note it.
3. Adjust the variable resistors (R2 and R2_FineAdjustment) till the unbalanced voltage is zero and the Bridge Balanced LED is on.
4. Note the value of R2 displayed at this condition
5. Verify if $\mathrm{R} 2 / \mathrm{R} 1=\mathrm{Rx} / \mathrm{R} 3$.

## Viva- voce Questions: -

1. What are the applications of a Wheatstone bridge?
2. What is the principle of the Wheatstone bridge?
3. Name the instrument that is used as a null detector in the Wheatstone bridge.
4. Why do we need LabVIEW?
5. What are the advantages of LabVIEW?

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| :---: | :---: |
| Electronics \& Instrumentation Department | Principall YJEC <br> Vimal Jyothi Engineering College |

## Result:

## Evaluation of Experiment: -

| SCORING CRITERIA | NO <br> PERFORMANCE <br> 0 | AVERAGE <br> 0.5 | SATISFACTORY <br> $\mathbf{1}$ | GOOD <br> 5 | EXCELLENT <br> 7.5 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  <br> Timely Completion |  |  |  |  |  |
| Basic <br> knowledge(VIVA) |  |  |  |  |  |
| Overall Performance <br> (Conduct of experiment <br>  <br> Observations) |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |

## Experiment No: 12

## Date:

## SIMULATION OF ANDERSON'S BRIDGE USING LabVIEW

## Aim: -

To simulate the operation of a Anderson's Bridge using LabVIEW.

## Components and equipments required: -

LabVIEW software, PC

## Theory: -

The Anderson's bridge gives the accurate measurement of self-inductance of the circuit. The bridge is the advanced form of Maxwell's inductance capacitance bridge. In Anderson bridge, the unknown inductance is compared with the standard fixed capacitance which is connected between the two arms of the bridge.
Constructions of Anderson's Bridge
The bridge has fours arms $\mathrm{ab}, \mathrm{bc}, \mathrm{cd}$ and ad . The arm ab consists unknown inductance along with the resistance. And the other three arms consist the purely resistive arms connected in series with the circuit.


## Anderson's Bridge

The static capacitor and the variable resistor are connected in series and placed in parallel with the $\mathbf{c d}$ arm. The voltage source is applied to the terminal a and c .

## Phasor Diagram of Anderson's Bridge

The phasor diagram of the Anderson bridge is shown in the figure below. The current $\mathbf{I}_{\mathbf{1}}$ and the $\mathbf{E}_{\mathbf{3}}$ are in phase and represented on the horizontal axis. Whes ighature Not visififed balance condition the voltage across the arm bc and ec are equal.


## Anderson's Bridge

The current enters into the bridge is divided into the two parts $\mathbf{I}_{\mathbf{1}}$ and $\mathbf{I}_{\mathbf{2}}$. The $\mathbf{I}_{\mathbf{1}}$ is entered into the arm ab and causes the voltage drop $\mathbf{I}_{\mathbf{1}}\left(\mathbf{R}_{1}+\mathbf{R}\right)$ which is in phase with the $\mathbf{I}_{\mathbf{1}}$. As the bridge is in the balanced condition, the same current is passed through the arms bc and ec.

The voltage drop $\mathbf{E}_{4}$ is equal to the sum of the $\mathbf{I}_{\mathbf{c}} / \omega \mathbf{C}$ and the $\mathbf{I}_{\mathbf{C}} \mathbf{r}$. The current $\mathbf{I}_{4}$ and the voltage $\mathbf{E}_{4}$ are in the same phase and representing on the same line of the pheasor diagram. The sum of the current $\mathbf{I}_{\mathbf{C}}$ and $\mathbf{I}_{4}$ will give rise to the current $\mathbf{I}_{\mathbf{2}}$ in the arm ad.

When the bridge is at balance condition the emf across the arm $\mathbf{a b}$ and the point $\mathbf{a}$, $\mathbf{d}$ and $\mathbf{e}$ are equal. The phaesor sum of the voltage across the arms ac and de will give rise the voltage drops across the arm ab.

## Procedure: -

1. Create a VI in LabVIEW with the following front panel and block diagram.

## FRONT PANEL



## BLOCK DIAGRAM


2. Set the values of R1 and L1 to a random value and note it.
3. Adjust the variable resistors r and r 1 till the balance achieve LED is on.
4. Note the value of rand r1 at this condition
5. Verify R1 = R2 R3/R4-r1

$$
\mathrm{L} 1=\mathrm{C}(\mathrm{R} 3 / \mathrm{R} 4)[\mathrm{r}(\mathrm{R} 4+\mathrm{R} 2)+\mathrm{R} 2 \mathrm{R} 4] .
$$

## Viva- voce Questions: -

1. What is the block diagram panel and Front Panel?
2. What Is The Difference Between Local Variable And Global Variable In Labview?
3. What is the principle of Anderson bridge?
4. Why capacitor is used in Anderson bridge?
5. What is the balance condition of Anderson bridge?

## Result:

Evaluation of Experiment: -

| SCORING CRITERIA | NO PERFORMANCE 0 | $\begin{gathered} \text { AVERAGE } \\ 0.5 \end{gathered}$ | $\begin{gathered} \text { SATISFACTORY } \\ 1 \end{gathered}$ | $\begin{gathered} \text { GOOD } \\ 5 \end{gathered}$ | $\begin{gathered} \text { EXCELLENT } \\ 7.5 \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Punctuality \& Timely <br> Comnlation |  |  |  |  |  |
| Basic knowledge(VIVA) |  |  |  |  |  |
| Overall Performance (Conduct of experiment / |  |  |  |  |  |
| Result |  |  |  |  |  |
| Total Marks(30) |  |  |  |  |  |

## LABORATORIES

1. ANALOGELECTRONICS LABORATORY

2. DIGITAL ELECTRONICS LABORATORY


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## 3. RESEARCH LABORATORY


4. DIGITAL SIGNAL PROCESSING LABORATORY


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ipal.VJEC

## 5. COMMUNICATION ENGINEERING LABORATORY



## ECL332 COMMUNICATION LAB

## MANUAL

For Sixth Semester B.Tech Degree Courses 2019 scheme
(As per APJ Abdul Kalam Technological University Syllabus)


Where perfection is the tradition

# VIMAL JYOTHI ENGINEERING COLLEGE 

(Affiliated to KTU \& Approved by AICTE NewDelhi)
JYOTHI NAGAR, CHEMPERI, KANNUR-670632
www.vjec.ac.in

## DEPARTMENT OF ELECTRONICS \& COMMUNICATION ENGINEERING

Prepared by:
Bindu Sebastian(Associate Professor)
Grace John M (Assistant Professor)
Designed By:
Sini Devassia (Trade Instructor)
Approved by :
Dr.D.Anto Sahaya Dhas (Professor \&אnfigal) VJEC

# ECL332 COMMUNICATION LAB 

## For S6 ECE B.Tech Degree Courses

(As per the APJ Abdul Kalam Technological University Syllabus)
2021-2022

Name of Student
Semester \& Branch $\qquad$

Roll No. $\qquad$

University Reg.No. $\qquad$

## CERTIFICATE

Certified that this is the bonafide record of the work done in the Communication Lab of Vimal Jyothi Engineering College Chemperi, Kannur by Mr./Ms. ------------------------------------------------during the year-

Date: $\qquad$
Place: $\qquad$

INDEX

| Sl.No. | Page <br> No. | Name of Experiment/Work Done | Marks | Signature of <br> Staff |
| :---: | :---: | :---: | :---: | :---: |
| 1 | 13 | Generation and Detection of BPSK |  |  |
| 2 | 15 | FM generation and demodulation using PLL |  |  |
| 3 | 21 | Error Performance of BPSK using Matlab |  |  |
| 4 | 23 | Error Performance of QPSK using Matlab |  |  |
| 5 | 27 | EYEDIAGRAM |  |  |
| 6 | 31 | PERFORMANCE OF WAVEFORM <br> CODING USING PCM |  |  |
| 7 | 37 | PULSE SHAPING AND MATCHED <br> FILTERING |  |  |
| 8 | 42 | FAMILIARIZATION WITH SOFTWARE <br> DEFINED RADIO (HARDWARE AND <br> CONTROL SOFTWARE |  |  |
| 9 | 49 | FM RECEPTION |  |  |

## ECL332 COMMUNICATION LAB

## COURSE OBJECTIVES

- The experiments are categorized into three parts Part A, Part B and Part C.
- The experiments in Part A involves design and setting up of prototype circuits on breadboard or trainer kits.
- The experiments in Part B are software simulations and can be done using GNU Octave or Python. Other software such as MATLAB/ SCILAB/Lab VIEW can also be used
- .The experiments in Part C are emulations using SDR (software-designed radio) dongle connected to laptops. A control software has to be in- stalled on the laptops. A combination of open-source GNU Radio soft- ware, RTLSDR (for reception) and HackRF / LimeSDR (for trans- mission) can be used to conduct these experiments. Other platforms such as Lab View with NI-USRP or Simulink with RTL-SDR can also be used


## COURSE OUTCOMES

After the completion of the course the student will be able to
CO 1 Setup simple prototype circuits for waveform coding and digital Modulation techniques working in a team.
CO 2 Simulate the error performance of a digital communication system using standard binary and M -ary modulation schemes.
CO 3 Develop hands-on skills to emulate a communication system with software-designedradio working in a team.

| ECL332 | COMMUNICATION LAB | CATEGORY | L | T | P | CREDIT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | PCC | $\mathbf{0}$ | $\mathbf{0}$ | 3 | 2 |

## Preamble:

- The experiments are categorized into three parts Part A, Part B and Part C.
- The experiments in Part A involves design and setting up of prototype circuits on breadboard or trainer kits.
- The experiments in Part B are software simulations and can be done using GNU Octave or Python. Other softwares such as MATLAB/ SCILAB/ LabVIEW can also be used.
- The experiments in Part C are emulations using SDR (software-designedradio) dongle connected to laptops. A control software has to be in- stalled on the laptops. A combination of open-source GNU Radio soft- ware, RTLSDR (for reception) and HackRF / LimeSDR (for trans- mission) can be used to conduct these experiments. Other platforms such as LabView with NI-USRP or Simulink with RTL-SDR can also be used.


## Prerequisites:

- ECT 305 Analog and Digital Communication
- ECT 303 Digital Signal Processing

Course Outcomes :The student will be able to

| CO 1 | Setup simple prototype circuits for waveform coding and digital <br> modulation techniques working in a team. |
| :--- | :--- |
| CO 2 | Simulate the error performance of a digital communication system <br> using standard binary and $M$-ary modulation schemes. |
| CO 3 | Develop hands-on skills to emulate a communication system with <br> software-designed-radio working in a team. |

Mapping of Course Outcomes with Program Outcomes

|  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| CO1 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 | 3 | 2 | 0 | 1 |
| CO2 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| CO3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 3 | 2 | 0 | 3 |

## Assessment Pattern Mark Distribution;

| Total Mark | CIE | ESE |
| :---: | :---: | :---: |
| 150 | 75 | 75 |

## Continuous Internal Evaluation Pattern:

| Attribute | Mark |
| :--- | :--- |
| Attendance | 15 |
| Continuous assessment | 30 |
| Internal Test (Immediately before | 30 |
| the second series test) |  |

End Semester Examination Pattern: The following guidelines should be followed regarding award of marks.

| Attribute | Mark |
| :--- | :--- |
| Preliminary work | 15 |
| Implementing the work/Conducting the experiment | 10 |
| Performance, result and inference (usage of equipments <br> and trouble shooting) | 25 |
| Viva voce | 20 |
| Record | 5 |

General instructions: End-semester practical examination is to be conducted immediately after the second series test covering entire syllabus given below. Evaluation is to be conducted under the equal responsibility of both the internal and external examiners. The number of candidates evaluated per day should not exceed 20. Students shall be allowed for the examination only on submitting the duly certified record. The external examiner shall endorse the record.

## Experiments

## Part A

Any two experiments are mandatory. The students shall design and setup simple prototype circuits with the help of available ICs. They can observe Waveforms produced by these circuits for standard ideal inputs.

1. FM generation and demodulation using PLL
2. Generation and Detection of PCM signals
3. Generation and Detection of Delta modulated signals
4. Generation and Detection of BPSK
5. Generation and Detection of $16-$ QPSK

## Part B

All experiments are mandatory. The students shall write scripts to simulate components of communication systems. They shall plot various graphs that help to appreciate and compare performance.

## 1. Performance of Waveform Coding Using PCM

1. Generate a sinusoidal waveform with a DC offset so that it takes only positive amplitude value.
2. Sample and quantize the signal using an uniform quantizer with number of representation levels $L$. Vary $L$. Represent each value using decimal to binary encoder.
3. Compute the signal-to-noise ratio in dB .
4. Plot the SNR versus number of bits per symbol. Observe that the SNR increases linearly.

## 2. Pulse Shaping and Matched Filtering

1. Generate a string of message bits.
2. Use root rasied cosine pulse $p(t)$ as the shapig pulse, and generate the corresponding baseband signal with a fixed bit duration $T_{b}$. You may use rolloff factor as $\alpha=0.4$.
3. Simulate transmission of baseband signal via an AWGN channel
4. Apply matched filter with frequency response $P_{r}(f)=P^{*}(f)$ to the received signal.
5. Sample the signal at $m T_{b}$ and compare it against the message sequence.

## 3. Eye Diagram

1. Generate a string of message bits.
2. Use rasied cosine pulse $p(t)$ as the shapig pulse, and generate the corresponding baseband signal with a fixed bit duration $T_{b}$. You may use rolloff factor as $\alpha=0.4$.
3. Use various roll off factors and plot the eye diagram in each case for the received signal. Make a comparison study among them.

## 4. Error Performance of BPSK

1. Generate a string of message bits.
2. Encode using BPSK with energy per bit $E_{b}$ and represent it using points in a signal-space.
3. Simulate transmission of the BPSK modulated signal via an AWGN channel with variance $N_{0} / 2$.
4. Detect using an ML decoder and plot the probability of error as a function of SNR per bit $E_{b} / N_{0}$.

## 5. Error Performance of QPSK

1. Generate a string of message bits.
2. Encode using QPSK with energy per symbol $E_{s}$ and represent it using points in a signal-space.
3. Simulate transmission of the QPSK modulated signal via an AWGN channel with variance $N_{0} / 2$ in both $I$-channel and $Q$-channel.
4. Detect using an ML decoder and plot the probability of error as a function of SNR per bit $E_{b} / N_{0}$ where $E_{s}=2 E_{b}$.

## Part C

Any two experiments are mandatory. The students shall emulate communication systems with the help of software-defined-radio hardware and necessary control software. Use available blocks in GNU Radio to implement all the signal processing. These experiments will help students to appreciate better how theoretical concepts are translated into practice.

## 1. Familiarization with Software Defined Radio (Hardware and Control Software)

1. Familiarize with an SDR hardware for reception and transmission of RF signal.
2. Familiarize how it can be interfaced with computer.
3. Familiarize with GNU Radio (or similar software's like Simulink/ Lab- View) that can be used to process the signals received through the SDR hardware.
4. Familiarize available blocks in GNU Radio. Study how signals can be generated and spectrum (or power spectral density) of signals can be analyzed. Study how filtering can be performed.

## 2. FM Reception

1. Receive digitized FM signal (for the clearest channel in the lab) using the SDR board.
2. Set up an LPF and FM receiver using GNU Radio.
3. Use appropriate sink in GNU Radio to display the spectrum of signal.
4. Resample the voice to make it suitable for playing on computer speaker.

## 3. FM Transmission

1. Use a wave file source.
2. Set up an FM transmitter using GNU Radio.
3. Resample the voice source and transmit using the SDR.

Schedule of Experiments Every experiment should be completed in three hours.

## Text books and References

1. Carl Laufer, "The Hobbyist's Guide to the RTL-SDR: Really Cheap Software Defined Radio"
2. Neel Pandeya, "Implementation of a Simple FM Receiver in GNU Ra- dio," https://kb.ettus.com/
3. WH Tranter, KS Shanmugan, TS Rappaport, KL Kosbar, "Principles of Communication Systems Simulation with Wireless Applications", Prentice Hall
4. Michael Ossmann, "Software Defined Radio with HackRF," YouTube Tutorial
5. Mathuranathan Viswanathan, "Digital Modulations using Python"

## ELECTRONICS ENGINEERING LAB RULES

1. Safety is first, work is next.
2. Each lab group will be assigned an area to store lab materials. Please store your components and other equipment only in your assigned area.
3. Make sure TEST instruments are set for proper FUNCTION AND RANGE prior to taking a measurement.
4. Equipment should not be removed, transferred to any location without permission from the laboratory staff.
5. Do not remove any parts or equipment from the lab without prior permission from the course coordinator or laboratory staff.
6. Report all equipment problems to laboratory staff.
7. Do not write on equipments and work table.
8. Do not put suspected defective parts back in the bins. Give them to laboratory staff for testing or disposal.
9. Return components and connecting wires, when you are finished with them.
10. Each group is responsible for the Lab bench. After the Lab exercise is over, all equipment should be powered down and disconnected from the socket, all probes, cords, etc. returned to their proper position. Do not cut and drop wires on the Lab bench. Your Lab grade will be affected if your bench is not tidy when you leave the Lab.
11. Lab clean up (to be accomplished at the end of each lab session):
i. Turn off test equipment.
ii. Put hand tools back on the pegboard rack.
iii. Clean bench top.
iv. Put stools under the bench.

## ASSESSMENT RUBRICS

| Scoring criteria | Average 4 | Satisfactory 6 | $\begin{gathered} \text { Good } \\ 8 \end{gathered}$ | Excellent 10 |
| :---: | :---: | :---: | :---: | :---: |
| Basic knowledge, conducting experiment and analyzing results | Missing several important experimental details or no idea about the experiment and incorrect interpretation of trends and comparison of data indicating a lack of understanding of results | Still missing some important experimental details and Some of the results have been correctly interpreted and discussed; partial but incomplete understanding of results is still evident | Important experimental details are covered, some minor details missing and almost all of the results have been correctly interpreted and discussed, only minor improvements are needed. | All experimental details are covered and excellent knowledge about the experiment and all important trends and data comparisons have been interpreted correctly and discussed, good understanding of results is conveyed |
| Record | Sections out of order, sloppy formatting and poor hand writing, Figures, graphs, tables contain errors or are poorly constructed, have missing titles, captions or numbers, units missing or incorrect, etc. | Sections in order, formatting is rough but readable ,Most figures, graphs, tables clear, still missing some important or required features | All sections in order, formatting generally good All figures, graphs, tables are correctly drawn, but some have minor problems or could still be improved | All sections in order, well-formatted, very readable, All figures, graphs, tables are correctly drawn, are numbered and contain titles/captions. |
| Viva | Only able to answer basic questions | Answer the questions, but fails to elaborate. | Answer the questions, but could elaborate only a few. | Answer the questions with explanations and elaboration |

## EVALUATION OF EXPERIMENTS

Performance in Conducting Experiment and Preparing Lab Record

| Scoring criteria | Average (4) | Satisfactory (6) | Good (8) | Excellent (10) |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :---: | :---: | :---: |
| Basic knowledge, conducting <br> experiment and analyzing results |  |  |  |  |  |  |  |
| Record |  |  |  |  |  |  |  |
| Viva |  |  |  |  |  |  |  |
| Total Marks for Performance in Conducting Experiment \& Record (30) |  |  |  |  |  |  |  |
| Signature of Staff : | Signature Not Verified |  |  |  |  |  |  |

## Experiment no. 1

## Date:

## Generation and Detection of BPSK

## AIM

To design and set up a BPSK modulator and demodulator circuit using AD633.

## COMPONENTS REQUIRED

IC AD633,Resistor,Capacitor,CRO,Signal generator,Power supply,Bread board etc.

## THEORY

The three basic modulation schemes are ASK, PSK and FSK. In coherent binary PSK system, the pair of signals $S(1)$ and $S 2(t)$ are used to represent binary 1 and 0 respectively and is defined as

Symbol 1, $s(t)=(\sqrt{ } 2 E b / T b) . \operatorname{Cos} 2 \pi f c t$
symbol $0,=S 2(t)=\quad)=(\sqrt{ } 2 E b / T b) \cdot \operatorname{Cos}(2 \pi$ fct $+\pi)$.
That is $)=(\sqrt{ } 2 \mathrm{~Eb} / \mathrm{Tb})$. Cos $2 \pi \mathrm{fct} \quad$ where $0 \leq \mathrm{t} \leq \mathrm{Tb}$.

In BPSK modulator amplitude and frequency are fixed. But the phase has value 0 for binary 1 and 180 or $\pi$ radians for binary 0 . Psk modulator can be achieved with the help of a product modulator AD633.

The schematic of AD 633 multiplier is as shown in fig. AD 633 is a four quadrant analog multiplier IC. It includes high impedence differential $X$ and $Y$ inputs and a high impedence summing input (z). The power supply ranges from +8 V to +18 V . The difference output is $\mathrm{X} 1-\mathrm{X} 2$ and $\mathrm{Y} 1-\mathrm{Y} 2$ are applied to the multiplier. The out put of a multiplier (X1-X2)(Y1-Y2)/10 is then applied to a zener reference. So in general ,output $(\mathrm{X} 1-\mathrm{X} 2)(\mathrm{Y} 1-\mathrm{Y} 2) / 10+\mathrm{z}$. To obtain PSK we make $\mathrm{Y} 2=\mathrm{X} 2=\mathrm{z}=0$ which gives out put $\mathrm{V} 0=\mathrm{X} 1 \mathrm{Y} 1 / 10$ at pin no. 7 . The carrier wave is given at X 1 which is a sine wave and a positive pulse train is appliedat Y 1 .

Coherent detection schemes are the simplest and easiest demodulation technologies. In this , the original carrier without demodulationis employed to demodulate PSK. It is evident that by instantaneous multiplication of PSK with carrier results in a ripple version of corresponding modulating signal. With the help of a proper intergrating, we can nullify the ripples to a great extent. Figheture Not jerified
is used as multiplier by providing PSK as one input and orginal carrier or the other input. The PSK output is integrated with a proper RC circuit to obtain the demodulated output.

## CIRCUIT DIAGRAM



## DESIGN

Let $\mathrm{f}=1 / 2 \pi \mathrm{RC}$
$\mathrm{F}=10 \mathrm{KHz}, \mathrm{C}=0.01 \mu \mathrm{~F} . \mathrm{R}=1 / 2 \pi \mathrm{fC}, \mathrm{R}=1.6 \mathrm{~K} \Omega$, select $\mathrm{R}=1.8 \mathrm{~K} \Omega$ std value.


Modulating Wave (digital)


| 0 | 1 | 0 | 0 |
| :--- | :--- | :--- | :--- |

Modulated Result


## PROCEDURE

Circuit is set up on the bread board.A squarewave of $10 \mathrm{Vpp}, 1 \mathrm{KHZ}$ and a sinusoidal signal of $4 \mathrm{Vpp}, 10 \mathrm{KHZ}$ is given as the modulating and carrier signal respectively and the PSK modulated signal and carrier signal is given as the input of second AD633.The o/p is given to the integrator and demodulated output is obtained.

## RESULT

BPSK modulator and demodulator circuit is designed and setup using AD633.

## Experiment No:2

## Date:

## FM generation and demodulation using PLL

## AIM:

To set up a frequency modulation and demodulation circuit using PLL IC.

## COMPONENTS REQUIRED:

IC CD4046, Resistors, Capacitors ,CRO ,Signal generator, Power supply, Bread Board

## THEORY

Phased-locked loops are available in integrated-circuit packages which contain a phasedetector and a VCO. The PLL we will use in the lab is the popular 4046. The VCO frequency range for the 4046 is determined by two external resistors and an external capacitor

Frequency modulator can be set up using the VCO inside the PLL chip carrier frequency of the modulator can be decided by selecting the appropriate values for $\mathrm{R} 1 \& \mathrm{C} 1$.The modulating signal is fed to the VCO input.

In the demodulator the PLL is locked on to the FM input signal, the VCO tracks the instantaneous frequency of the signal. Phase comparator gives an output voltage propotional to the frequency deviation of FM input. Phase comparator -1PC-1)) is the PLL is used here because with PC2,if the input is a sine wave, the frequency must be greater than 10 KHz . Also $\mathrm{PC}-1$ has better signal input noise rejection characterstics. The VCO frequencyof the modulator and demodulator must be same.

The FM demodulator is done with the help of a circuit called Phase Locked Loop (PLL). A PLL should have basic functional blocks like Voltage Controlled Oscillator (VCO), Phase comparator, Low Pass Filter (LPF) and Source follower. In the demodulator circuit the VCO generates a frequency which matches the original carrier frequency and compares the phase of that with received FM wave using the Phase comparator. The output of the Phase comparator is filtered out using the LPF and is current amplified using a Source follower. The output of the source follower matches the original message signal.

CIRCUIT DIAGRAM:

Modulator


## Demodulator



Pin diagram of 4046:-


## DESIGN

## Modulator:

$\mathrm{V}=\mathrm{Vcc}=10 \mathrm{v}$

Control voltage $\mathrm{Vc}=\mathrm{V} * \mathrm{R} 3 /(\mathrm{R} 3+\mathrm{R} 2)$

Vc must be between $3 / 4^{\text {th }}$ voltage V and the voltage V

$$
\begin{aligned}
\mathrm{V} \mathrm{c} & =3 / 4 * 10 \\
& =7.5
\end{aligned}
$$

Let R2 $=10 \mathrm{~K} \Omega$
$7.5=10 * \mathrm{R} 3 /\left(10^{*} 10^{\wedge} 3+\mathrm{R} 3\right)$
$7.5 * \mathrm{R} 3+7.5 * 10^{*} 10^{\wedge} 3=10 * \mathrm{R} 3$
$75 * 10^{\wedge} 3=2.5 * \mathrm{R} 3$
$\mathrm{R} 3=30 \mathrm{~K} \Omega$ ( $33 \mathrm{~K} \Omega$ std )

Frequency produced by $\mathrm{VCO}=\mathrm{f}=2.4(\mathrm{~V}-\mathrm{Vc}) / \mathrm{V} * \mathrm{R} 1 * \mathrm{C} 1$

Let $\mathrm{f}=100 \mathrm{KHz}$

```
    R1=4.7K\Omega
100*10^3=2.4(10-7.5)/10*4.7*10^3*C1
C1=2.4*2.5/100/10^3*4.7*10^3
    1.29*10^-9
C1=0.0012*10^-6
    0.0012\mu\textrm{F}
Set C2=0.1\muF
```


## Design : Demodulator

Let the center frequency of VCO is

$$
\mathrm{f}=1.2 /\left(\mathrm{VR}_{3} \mathrm{C}_{3}\right)
$$

Let $\mathrm{f}=100 \mathrm{KHz}, \mathrm{V}=10 \mathrm{~V}$ and $\mathrm{C}_{3}=0.001 \mu \mathrm{~F}$
$\mathrm{R}_{3}=1.2 \mathrm{~K} \Omega$

## Expected waveform



FM Modulated \& Demodulated o/p waveforms


## PROCEDURE

1. Set up the circuit as shown in figure after testing the components.
2. Manually trace the circuit to check the correctness of physical connection.
3. Set the bias voltages and input signal.
4. Complete the experimental set up by connecting the amplifier circuit with power source and CRO.

## RESULT

Designed and set up frequency modulator and demodulator using CD4046.

## Experiment No:3

## Date:

## ERROR PERFORMANCE OF BPSK

## AIM

Write a program to simulate transmission of the BPSK modulated signal via an AWGN channel and plot the probability of error as a function of SNR.

## ALGORITHM:

1.Generate a string of message bits.
2.Encode using BPSK with energy per bit Eb and represent it using points in a signal-space.
3.Simulate transmission of the BPSK modulated signal via an AWGN channel with variance $\mathrm{N} 0 / 2$.
4.Detect using an ML decoder and plot the probability of error as a function of SNR per bit $\mathrm{Eb} / \mathrm{N} 0$.

## THEORY

Binary Phase-shift keying (BPSK) is a digital modulation scheme that conveys data by changing, or modulating, two different phases of a reference signal (the carrier wave). The constellation points chosen are usually positioned with uniform angular spacing around a circle._Binary Phase Shift Keying (BPSK) is a two phase modulation scheme, where the 0 's and 1 's in a binary message are represented by two different phase states in the carrier signal: $\theta=0^{\circ}$ for binary 1 and $\theta=180^{\circ}$ for binary 0 .

## PROGRAM

\% Eb/N0 Vs BER for BPSK Modulation over Rayleigh Channel and AWGN
clc;clear;
$\mathrm{N}=10^{\wedge} 6$; \%Number of BPSK symbols to transmit
$\mathrm{d}=\operatorname{rand}(1, \mathrm{~N})>0.5$; \%binary data
$\mathrm{x}=2 * \mathrm{~d}-1 ; \%$ BPSK symbols $0->-1,1->1$
$\mathrm{EbNOdB}=-5: 2: 20$; \%Range of $\mathrm{Eb} / \mathrm{N} 0$ values
\%simBER_rayleigh=zeros(1,length(EbN0dB));
\%simBER_awgn=zeros(1,length(EbN0dB));
for $\mathrm{i}=1$ :length(EbN0dB),
noise $=1 /$ sqrt $(2) *\left(\operatorname{randn}(1, \mathrm{~N})+1 i^{*}\right.$ randn $\left.(1, \mathrm{~N})\right)$; \%AWGN noise with mean=0 var=1
\%h=1/sqrt(2)*(randn(1,N)+1i*randn(1,N)); \%Rayleigh Flat Fading factor- single tap
$\mathrm{n}=$ noise ${ }^{*} 10^{\wedge}(-\mathrm{EbN} 0 \mathrm{~dB}(\mathrm{i}) / 20)$; \%Scaling the noise for required $\mathrm{Eb} / \mathrm{N} 0$
y_awgn=x+n; \%received signal through AWGN channel
\% y_rayleigh=h.*x+n; \%received signal through Rayleigh channel
\% \%Coherent Receiver for Rayleigh Channel
\% y_rayleigh_cap=y_rayleigh./h; \%Assuming that h is known at the signal accurately
\% r_rayleigh=real(y_rayleigh_cap)>0; \%received symbols $=1$ is real part >0 or else it is 0
\% \%Receiver for AWGN channel
r_awgn=real(y_awgn)>0;
\%simBER_rayleigh(i)=sum(xor(d,r_rayleigh));
simBER_awgn(i)=sum(xor(d,r_awgn));
end
\%simBER_rayleigh=simBER_rayleigh/N;
simBER_awgn=simBER_awgn/N;
\%Theoretical BER;
$\mathrm{EbN} 0=10 .^{\wedge}(\mathrm{EbNOdB} / 10) ; \% \mathrm{~Eb} / \mathrm{N} 0$ in Linear Scale
\%theoretical_rayleigh $=0.5^{*}(1-\mathrm{sqrt}(\mathrm{EbN} 0 . /(1+\mathrm{EbN} 0)))$;
theoretical_awgn $=0.5 * \operatorname{erfc}(\operatorname{sqrt}(\mathrm{EbNO}))$;
\%semilogy(EbN0dB,simBER_rayleigh,'g*-','LineWidth',2);hold on;
semilogy(EbNOdB,simBER_awgn,'r*-','LineWidth',2);hold on;
\%semilogy(EbN0dB,theoretical_rayleigh,'ko','LineWidth',2); hold on
semilogy(EbN0dB,theoretical_awgn,'bo','LineWidth',2);grid on;
axis([-5 $\left.\left.2010^{\wedge}-51.2\right]\right)$;
legend('Simulated AWGN','Theoretical awgn');
title('Eb/N0 Vs BER for BPSK over AWGN Channels');
xlabel('Eb/NO(dB)');
ylabel('Bit Error Rate or Symbol Error Rate');

## Expected Graph



## RESULT:

Executed the program and verified the results.

## Experiment No: 4

## Date:

## ERROR PERFORMANCE OF OPSK

## AIM

Write a program to simulate transmission of the QPSK modulated signal via an AWGN channel and plot the probability of error as a function of SNR

## ALGORITHM

1. Generate a string of message bits.
2. Encode using BPSK with energy per bit $E_{b}$ and represent it using points in a signal-space.
3. Simulate transmission of the QPSK modulated signal via an AWGN channel with variance $N_{0} / 2$ in both l-channel and $Q$-channel.
4.Detect using an ML decoder and plot the probability of error as a function of SNR per bit $E_{b} / N_{0}$ where $E_{s}=2 E_{b}$.
4. Detect using an ML decoder and plot the probability of error as a function of SNR per bit $E_{b} / N_{0}$.

THEORY

Quadrature Phase Shift Keying (QPSK) is a form of phase modulation technique, in which two information bits (combined as one symbol) are modulated at once, selecting one of the four possible carrier phase shift states.


The QPSK signal within a symbol duration $T_{\text {sym }}$ is defined as

$$
\begin{equation*}
s(t)=A \cos \left[2 \pi f_{c} t+\theta_{n}\right] \quad, 0 \leq t \leq T_{s y m}, n=1,2,3,4 \tag{1}
\end{equation*}
$$

where the signal phase is given by

$$
\begin{equation*}
\theta_{n}=(2 n-1) \frac{\pi}{4} \tag{2}
\end{equation*}
$$

Therefore, the four possible initial signal phases are $\pi / 4,3 \pi / 4,5 \pi / 4$ and $7 \pi / 4$ radians. Equation (1) can be re-written as

$$
\begin{align*}
s(t) & =A \cos \theta_{n} \cos \left(2 \pi f_{c} t\right)-A \sin \theta_{n} \sin \left(2 \pi f_{c} t\right) \\
& =s_{n i} \phi_{i}(t)+s_{n q} \phi_{q}(t) \tag{3}
\end{align*}
$$

The above expression indicates the use of two orthonormal basis functions: $\left\langle\phi_{i}(t), \phi_{q}(t)\right\rangle$ together with the inphase and quadrature signaling points: $\left\langle s_{n i}, s_{n q}\right\rangle$. Therefore, on a two dimensional co-ordinate system with the axes set to $\phi_{i}(t)$ and $\phi_{q}(t)$, the QPSK signal is represented by four constellation points dictated by the vectors $\left\langle s_{n i}, s_{n q}\right\rangle_{\text {with }} n=1,2,3,4$.

## PROGRAM

\% Demonstration of Eb/N0 Vs BER for QPSK modulation scheme clear;
clc;
\%---------Input Fields
$\mathrm{N}=1000000 ; \%$ Number of input bits
$\mathrm{EbN} 0 \mathrm{~dB}=-4: 2: 10 ; \% \mathrm{~Eb} / \mathrm{N} 0$ range in dB for simulation
\%
data $=\operatorname{randn}(1, \mathrm{~N})>=0 ; \%$ Generating a uniformly distributed random 1 s and 0 s
oddData $=\operatorname{data}(1: 2:$ end $)$;
evenData $=$ data(2:2:end);
qpskModulated $=\operatorname{sqrt}(1 / 2) *\left(1 i^{*}(2 *\right.$ oddData-1 $)+(2 *$ evenData-1) $) ;$ \%QPSK Mapping
$\mathrm{M}=4$; \%Number of Constellation points $\mathrm{M}=2^{\wedge} \mathrm{k}$ for QPSK $\mathrm{k}=2$
$\mathrm{Rm}=\log 2(\mathrm{M}) ; \% \mathrm{Rm}=\log 2(\mathrm{M})$ for $\mathrm{QPSK} \mathrm{M}=4$
$\mathrm{Rc}=1$; \% $\mathrm{Rc}=$ code rate for a coded system. Since no coding is used $\mathrm{Rc}=1$
$B E R=$ zeros(1,length $(E b N 0 d B)$ ); \%Place holder for BER values for each $\mathrm{Eb} / \mathrm{N} 0$
index=1;
for $\mathrm{i}=\mathrm{EbNOdB}$,
\%--------------------------------------------
\%Channel Noise for various $\mathrm{Eb} / \mathrm{N} 0$
\%----------------------------------------------
\%Adding noise with variance according to the required $\mathrm{Eb} / \mathrm{N} 0$
$\mathrm{EbN} 0=10 . \wedge(\mathrm{i} / 10)$; \%Converting $\mathrm{Eb} / \mathrm{N} 0 \mathrm{~dB}$ value to linear scale noiseSigma $=\operatorname{sqrt}(1 . /(2 * R m * R c * E b N 0)) ; \%$ Standard deviation for AWGN Noise
\%Creating a complex noise for adding with QPSK modulated signal
\%Noise is complex since QPSK is in complex representation
noise $=$ noiseSigma $*\left(\operatorname{randn}(1\right.$, length $(q p s k M o d u l a t e d))+1 i^{*}$ randn(1,length $($ qpskModulated $\left.)\right)$ );
received $=$ qpskModulated + noise;
\%
\%Threshold Detector
detected_real $=$ real(received) $>=0$;
detected_img $=$ imag $($ received $)>=0$;
estimatedBits=reshape([detected_img;detected_real],1,[]);
\%
\%Bit Error rate Calculation
BER(index) $=\operatorname{sum}(\operatorname{xor}($ data,estimatedBits $)) /$ length $($ data $) ;$
index=index+1;
end
\%Plot commands follows
plotHandle $=$ plot(EbN0dB, $\log 10$ (BER),'r--');
set(plotHandle,'LineWidth',1.5);
title('SNR per bit (Eb/N0) Vs BER Curve for QPSK Modulation Scheme');
xlabel('SNR per bit (Eb/N0) in dB');
ylabel('Bit Error Rate (BER) in dB');
grid on;
hold on;
theoreticalBER $=0.5^{*} \operatorname{erfc}(\operatorname{sqrt}(10 . \wedge(E b N 0 \mathrm{~dB} / 10))$ );
plotHandle=plot(EbN0dB,log10(theoreticalBER),'b*');
set(plotHandle,'LineWidth',1.5);
legend('Simulated','Theoretical-QPSK','Theoretical-QPSK'); grid on;

## Expected graph



## RESULT:

Executed the program and verified the results.

Date:

## EYE DIAGRAM

## AIM:

## Write a program to plot eye diagram.

## ALGORITHM:

1. Generate a string of message bits.
2. Use rasied cosine pulse $p(t)$ as the shapig pulse, and generate the corresponding baseband signal with a fixed bit duration $T_{b}$. You may use roll-off factor as $\alpha=$ 0.4 .
3. Use various roll off factors and plot the eye diagram in each case for the received signal. Make a comparison study among them.

## THEORY

The Eye Diagram block displays multiple traces of a modulated signal to produce an eye diagram. You can use the block to reveal the modulation characteristics of the signal, such as the effects of pulse shaping or channel distortions. Eyediagram( x, n, period, offset, plotstring, h ) generates the eye diagram in an existing figure whose handle is $h$. Use of hold on to plot multiple signals in the same figure is not supported. $\mathrm{h}=$ eyediagram $\qquad$ ) returns the handle to the figure that contains the eye diagram.

## PROGRAM

\%Baseband pulse shaping with raised cosine
close all; clear all; clc;
dt=0.01;
$\mathrm{n}=-20$ :dt:20;
$\mathrm{Nc}=4$;
$\mathrm{t}=-\mathrm{Nc}: \mathrm{dt}: \mathrm{Nc}$; \%length of shaping cosine pulse
$\mathrm{bt}=-1: \mathrm{dt}: 1$; \%two bit time
$\mathrm{bl}=\operatorname{size}(\mathrm{bt}, 2)-1 ; \%$ two bit length
bitfill=zeros(size(dt:dt:1));
b1=[1,bitfill];
b0 $=[-1$, bitfill $]$;
bits=[b0,b1,b0,b0,b1,b1,b0,b0,b0,b1,b1,b1,b0,b0,b0, b0,b1,b1,b1,...
b1,b1,b0,b0,b0,b0,b0,b0,b0,b0,b0,b1,b1,b1,b1,b1,b0, b0,b0,b0,...
b0,b1,b1,b1,b0,b1,b0,b0,b0,b1,b0,b0,b1,b1,b1,b0,b1, b0,b1,b0];\% bit stream
$\mathrm{b}=0.25$; \%beta value
$\left.\mathrm{ps}=\cos \left(\mathrm{pi}{ }^{*} \mathrm{~b}^{*} \mathrm{t}\right) . /\left(1-\left(2^{*} \mathrm{~b}^{*} \mathrm{t}\right)\right)^{\wedge}\right) . * \sin \left(\mathrm{pi}^{*} \mathrm{t}\right) . /\left(\mathrm{pi}^{*} \mathrm{t}\right)$;
\%raised cosine function
$\mathrm{ps}(\operatorname{isnan}(\mathrm{ps}))=1$;
$\mathrm{ps}(\operatorname{isinf}(\mathrm{ps}))=0$;
baseband=conv(bits,ps);
\%\%if noise to be added uncomment this part
$\mathrm{snr}=10 ; \% \mathrm{~dB}$
baseband=awgn(baseband,snr);
plot(t,ps)
title('raised cosine pulse');
figure
plot(baseband)
title('baseband');
grid on;
figure
eyedia=[];
$\mathrm{r}=0$;
for $\mathrm{i}=\mathrm{Nc} *(\mathrm{bl}+1)+1: \mathrm{bl} / 2+1$ :size(baseband, 2$)-\mathrm{Nc} * \mathrm{bl}$
$\% \mathrm{r}=\mathrm{randi}(\mathrm{bl} / 4)$; \% comment if no time jitter is
required
i=i+r;
eyedia=[eyedia;baseband(i:i+bl)];
end
plot(bt,eyedia');
title('Eye Diagram');
grid on

## Expected Graph





RESULT:
The Matlab program is executed and verified .

## Experiment No:6

Date:
PERFORMANCE OF WAVEFORM CODING USING PCM

## AIM:

The performance measure of PCM using MATLAB.

1. Generate a sinusoidal waveform with a DC offset so that it takes only positive amplitude value.
2. Sample and quantize the signal using an uniform quantizer with number of representation levels L. Vary L. Represent each value using decimal to binary encoder.
3. Compute the signal-to-noise ratio in dB .
4. Plot the SNR versus number of bits per symbol. Observe that the SNR increases linearly.

## THEORY:

Modulation is the process of varying one or more parameters of a carrier signal in accordance with the instantaneous values of the message signal.
The message signal is the signal which is being transmitted for communication and the carrier signal is a high frequency signal which has no data but is used for long distance transmission.
There are many modulation techniques, which are classified according to the type of modulation employed. Of them all, the digital modulation technique used is Pulse Code Modulation PCM.
A signal is pulse code modulated to convert its analog information into a binary sequence,i.e., $1 \mathbf{s}$ and $\mathbf{0 s}$. The output of a PCM will resemble a binary sequence. The following figure shows an example of PCM output with respect to instantaneous values of a given sinewave.


Instead of a pulse train, PCM produces a series of numbers or digits, and hence this process is called as digital. Each one of these digits, though in binary code, represent the approximate amplitude of the signal sample at that instant.
In Pulse Code Modulation, the message signal is represented by a sequence of coded pulses. This message signal is achieved by representing the signal in discrete form in both time and amplitude.

## Basic Elements of PCM

The transmitter section of a Pulse Code Modulator circuit consists of Sampling, Quantizing and Encoding, which are performed in the analog-to-digital converter section. The low pass filter prior to sampling prevents aliasing of the message signal. The basic operations in the receiver section are regeneration of impaired signals, decoding, and reconstruction of the quantized pulse train. Following is the block diagram of PCM which represents the basic elements of both the transmitter and the receiver sections.

## Figure: Block Diagram of PCM System



## Low Pass Filter

This filter eliminates the high frequency components present in the input analog signal which is greater than the highest frequency of the message signal, to avoid aliasing of the message signal.

## Sampler

This is the technique which helps to collect the sample data at instantaneous values of message signal, so as to reconstruct the original signal. The sampling rate must be greater than twice the highest frequency component W of the message signal, in accordance with the sampling theorem.
Sampling is defined as,"The process of measuring the instantaneous values of continuous-time signal in
A discrete form."Sample is a piece of data taken from the whole data which is continuous in the time domain.
When a source generates an analog signal and if that has to be digitized, having 1s and 0s i.e., High or Low, the signal has to be discretized in time. This discretization of analog signal is called as Sampling.

## Quantizer

Quantizing is a process of reducing the excessive bits and confining the data. The signature Not Verified
sampled output when given to Quantizer, reduces the redundant bits and compresses the value.
The digitization of analog signals involves the rounding off of the values which are approximately equal to the analog values. The method of sampling chooses a few points on the analog signal and then these points are joined to roundoff the value to a near stabilized value .Such a process is called as Quantization. The analog-to-digital converters perform this type of function to create a series of digital values out of the given analog signal. The following figure represents an analog signal.This signal to get converted in to digital ,has to under go sampling and quantizing.
The quantizing of an analog signal is done by discretizing the signal with a number of quantization levels. Quantization is representing the sampled values of the amplitude by a finite set of levels, which means converting a continuous-amplitude sample in to a discrete-time signal

## Encoder

The digitization of analog signal is done by the encoder. It designates each quantized levelby a binary code. The sampling done here is the sample-and-hold process. These threesections LPF, Sampler, and Quantizer will act as an analog to digital converter. Encodingminimizesthebandwidthused.

## RegenerativeRepeater

Thissectionincreasesthesignalstrength.Theoutputofthechannelalsohasoneregenerati ve repeater circuit, to compensate the signal loss and reconstruct the signal, andalsotoincreaseits strength.

## Decoder

The decoder circuit decodes the pulse coded waveform to reproduce the original signal. Thiscircuit actsas thedemodulator.

## ReconstructionFilter

After the digital-to-analog conversion is done by there generative circuit and the decoder,alow-passfilter is employed, called as there construction filter to get back the original signal.
Hence,thePulseCodeModulatorcircuitdigitizesthegivenanalogsignal,codesitandsam plesit,andthentransmitsitinananalogform. Thiswholeprocessisrepeatedinareversepat terntoobtaintheoriginal signal.

## MatlabCode

\% \% Performance of Waveform Coding Using PCM
\% 1. Generate a sinusoidal waveform with a DC offset so that it takes only \%positive amplitude value.
\% 2. Sample and quantize the signal using an uniform quantizer with number of
\%representation levels L. Vary L. Represent each value using decimal to \%binary encoder.
\% 3. Compute the signal-to-noise ratio in dB .
\% 4. Plot the SNR versus number of bits per symbol. Observe that the SNR
\%increases linearly.
close all; clear all; clc;
dt=0.01;
$\mathrm{t}=0: \mathrm{dt}: 5$; \%time axis
$\mathrm{Nb}=2$;\% number of bits
$\mathrm{L}=2^{\wedge} \mathrm{Nb}$; \% number of levels
$\mathrm{f}=1 ; \%$ frequency
A=1;\%offset
$\mathrm{s}=\mathrm{A}+\sin \left(2 * \mathrm{pi}^{*} \mathrm{f}^{*} \mathrm{t}\right)$;
\%sample the signal
$\mathrm{T}=0.04$; \%sampling time
$\mathrm{Tn}=$ round(T/dt);
tn=t(1:Tn:end);
$\mathrm{xn}=\mathrm{s}(1: \mathrm{Tn}:$ end);
figure;plot(t,s);
hold on
stem(tn,xn);
title('sampled signal');
\%legend('Signal','Sampled');
\%quantize to L levels
vmin=0;
vmax $=\max (\mathrm{s})$;
levels=linspace(vmin,vmax,L+1); \%level boundaries codebook
stepsize=levels(3)-levels(2);
$\mathrm{qs}=\mathrm{xn}$; \%quantized signal initialize
pcm=xn;
for $\mathrm{i}=2$ :length(levels)
idx=xn>=levels(i-1)\&xn<=levels(i);
qs(idx)=levels(i)-stepsize/2;
pcm(idx)=i-2;\%dec2bin(i-2,Nb);
end
qst=upsample(qs,Tn);
$\mathrm{qst}=\operatorname{conv}(\mathrm{qst}, \mathrm{ones}(1, \mathrm{Tn}))$;
$\operatorname{Tn} 2=\operatorname{round}(\operatorname{Tn} / 2)$;
$\% \mathrm{Tn} 2=1$;
$\mathrm{qst}=\mathrm{qst}(\mathrm{Tn} 2: \operatorname{size}(\mathrm{t}, 2)+\mathrm{Tn} 2-1)$;
qerr $=\mathrm{s}$-qst; \%qunatization error
\%plot images
figure; plot(t, s);
hold on
stairs(t,qst);
plot(t,qerr);
title('quantised signal');
\%legend('Signal','Quantized','Quantization error');
sigpow $=\operatorname{sum}\left(\mathrm{s}^{\wedge} 2\right)$;
noisepow=sum(qerr.^2);
$\operatorname{snr}=10 * \log 10$ (sigpow/noisepow);
figure
PCMbinCode=dec2bin(pcm,3);
stem ( pcm ); title('PCM code integer values');
display('signal to noise ratio in $\mathrm{dB}^{\prime}$, num2str(snr));
figure('name' , 'snr');
plot(t,snr);

## Expected Graph





RESULT: Implemented PCM using Matlab.

## Experiment No:7

Date:

## PULSE SHAPING AND MATCHED FILTERING

## AIM

The aim of this experiment is to write code in Octave for implementing the following:

1. Generate a string of message bits.
2. Use root rasied cosine pulse $p(t)$ as the shaping pulse, and generate the corresponding baseband signal with a fixed bit duration Tb . You may use roll-off factor as $\alpha=0.4$.
3. Simulate transmission of baseband signal via an AWGN channel
4. Apply matched filter with frequency response $\operatorname{Pr}(\mathrm{f})=\mathrm{P} *(\mathrm{f})$ to the received signal.
5. Sample the signal at mTb and compare it against the message sequence.

## THEORY

In communication systems, data is transmitted as binary bits (ones and zeros). It is easier to implement a binary system using switches, where turning on a switch represents ' 1 ' and turningit off represents ' 0 '. Such simple binary systems essentially represent ones and zeros as rectangular pulses of finite duration (say $\tau$ seconds).In practical terms, signals will not extend infinitely forward and backward in time. But it willdefinitely be non-zero after the time duration $\tau$. This implies that the residues of adjacentsymbols/signals overlap with each other giving rise to Inter Symbol Interference (ISI). If theresidual energy from the adjacent symbol is very strong, it becomes impossible to distinguish the present symbol and there is a possibility of it being misinterpreted altogether. To avoid or reduce this effect, "Pulse Shaping" techniques are used to make sure that the data carried by the symbols are not affected by the overlapping effect of adjacent symbols.
In a band-limited system, when we try to increase the data rate, it may lead to Inter Symbol Interference (ISI). There are two criteria that must be satisfied for a noninterference system when pulse shaping is employed.
(1) The pulse shape exhibits a zero crossing at the sampling point of all pulse intervals.
(2) The shape of the pulses is such that the amplitude decays rapidly outside of the
pulse interval.
Pulse shapes filters like raised cosine filters, square root raised cosine filters and matched filters are employed to shape the transmitted pulses so that they will satisfy the above two criteria of providing an ISI free system Square Root Raised Cosine Filter.

Instead of using a single Raised Cosine filter at the transmitter, a square root raised cosine filter is used at both transmitter and receiver. Using a single raised cosine filter at the transmitter or two separate SRRC filters (one at the transmitter and another at the receiver) will have the same effect on ISI. But using SRRC filters at the transmitter and receiver provides better matching characteristics and thereby improves the overall SNR of the system considerably. The impulse response of the SRRC filter is given by

$$
\begin{align*}
p(t=0) & =\frac{1}{\sqrt{T_{\text {sym }}}}\left[(1-\beta)+\frac{4 \beta}{\pi}\right] \\
p\left(t= \pm \frac{T_{\text {sym }}}{4 \beta}\right) & =\frac{\beta}{\sqrt{2 T_{\text {sym }}}}\left(\left[1+\frac{2}{\pi}\right] \sin \left[\frac{\pi}{4 \beta}\right]+\left[1-\frac{2}{\pi}\right] \cos \left[\frac{\pi}{4 \beta}\right]\right) \tag{5}
\end{align*}
$$

## PROGRAM

## Matlab function to implement Square Root Raised Cosine Filter

```
function [response]=srrc(os_factor,roll_off)
a=.4;
t=-4:1/os_factor:4;
p=zeros(1,length(t));
for i=1:1:length(t)
if t(i)==0 p(i)= (1-a)+4*a/pi;
elseif t(i)==1/(4*a)|t(i)==-1/(4*a) p(i)=a/sqrt(2)*((1+2/pi)*sin(pi/(4*a)+(1-
2/pi)*\operatorname{cos(pi/(4*a))));}
else p(i)=(\operatorname{sin}(p\mp@subsup{i}{}{*}t(i)*(1-a))+4*a*t(i).*\operatorname{cos}(p\mp@subsup{i}{}{*}t(i)*(1+a)))./(pi*t(i).*(1-(4*a*t(i)).^2));
end
end
response = p./sqrt(sum(p.^2));
end
```


## Simulation of Square Root Raised Cosine Filter in Matlab:

clc;
clear;

```
close all;
overSampling_Factor=8;
Input_bit = [1];
Input_bit_os=upsample(Input_bit,overSampling_Factor);
alpha=0.1;
pt = srrc(overSampling_Factor,alpha);
output_of_srrc_filter = conv(Input_bit_os,pt);
figure
%subplot(3,1,1);
stem(output_of_srrc_filter);
title('Response of SRRC Filter at Tx side')
xlabel('Samples')
ylabel('Amplitude')
output_of_srrc_filter=awgn(output_of_srrc_filter,100);
y = conv(output_of_srrc_filter,pt);
figure
%subplot(3,1,2);
stem(y);
title('Matched filter (SRRC) response at Rx side');
xlabel('Samples');
ylabel('Amplitude');
midSample=length(-4:1/overSampling_Factor:4);
y_truncated=y(midSample-1:end);
y_down = downsample(y_truncated,overSampling_Factor,1);
figure
%subplot(3,1,3);
stem(y_down);
title('Down sampled output (ADC conversion and Sampling)');
xlabel('Samples');
ylabel('Amplitude');
```





RESULT: Implemented pulse shaping and matched filter.

## PART C

## ExperimentNo:8

## Date:

## FAMILIARIZATION WITH SOFTWARE DEFINED RADIO (HARDWARE AND CONTROL SOFTWARE

## AIM:

1.To Familiarize with an SDR hardware for reception of RF signal.
2.To Familiarize how it can be interfaced with computer.

Hardware Required

- RTL SDR dongle
. A PC or a Raspberry Pi


## RTL SDR dongle



## RTL SDR Dongle



## Block diagram of the dongle




## Software Required

- Download SDR software -Airspy(sdrsharp)


## Installation Procedure

## Step 1 : Download SDR software

```
https://airspy.com > download \vdots
SDR Software Download - Airspy
This package contains: SDR# (SDRSharp) revision 1878 (2022-07-26) - The best free SDR
software for Airspy and RTL-SDR dongles!
Quick start guide · Spyserver status map Reviews
```



Step 2 : Extract the downloaded files to the specified destination


Step 3 : Install rtlsdr

| § sdrsharp-x86 (evaluation copy) |  |  |  |  |  | - |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| File Commands Tools Favorites Options Help |  |  |  |  |  |  |
|  | $\underset{\text { Test }}{2}$ |  |  |  |  |  |
| ( A C:\User | dent02\Dow | wnloads\sdrsharp-x86 |  |  |  | $\checkmark$ |
| Name * | Size | Type | Modified |  |  | - |
| 且.. |  | File folder |  |  |  |  |
| ]. Plugins |  | File folder | 2/20/2021 12:2... |  |  |  |
| (3) airspy.dll | 103,344 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) airspyhf.dll | 308,144 | Application extens... | 8/3/2022 12:09 ... |  |  | E |
| 2) api-ms-win-cor... | 13,232 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (a) BandPlan.xml | 10,579 | XML Document | 9/9/2020 1:50 ... |  |  |  |
| - D3DCompiler_4... | 4,112,816 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) hackrf.dll | 89,520 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| - ${ }^{\text {a }}$ httpget.exe | 192,512 | Application | 1/27/2021 11:1... |  |  |  |
| [0] install-tlisdr.bat | 499 | Windows Batch File | 1/27/2021 11:1... |  |  |  |
| (3) libusb-1.0.dll | 107,440 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) msvcr100.dll | 778,160 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) msver120.dll | 965,040 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) PenImc_cor3.dll | 142,768 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (a) Plugins.xml | 161 | XML Document | 1/27/2021 8:41 ... |  |  |  |
| (3) PortAudio.dll | 92,080 | Application extens... | 8/3/2022 12:09 ... |  |  |  |
| (3) PresentationNat... | 945,584 | Application extens... | 8/3/2022 12:09 ... |  |  | - |
| $\square \mathrm{mal}$ Selected 499 bytes in 1 file |  |  |  |  | Total 1 folder and 100,235,633 bytes in 30 files |  |






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Infleting: thirel-sdr-release/moa/rtireprom-s


infleting: tnairtiosdrareleasermotirtlosidr-wx


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2rass may key to contemue

Signature Not Verified

Principal.VJEC


Step 4: Install drivers


## RESULT:

Familiarized with SDR RTL Dongle .

Signature Not Verified

Principal.VJEC

## Experiment 9

## Date:

## FM RECEPTION

## Aim:

To receive FM signal from a nearby station using the SDR hardware

## Components and Equipments required:

RTL SDR dongle, laptop(desktop) SDR sharp installed, headphones or speakers. If your computer has inbuilt speakers no need of external connection.

## PROCEDURE

Step 1: Plug in the RTL SDR dongle and run sdrrtl software.
Step 2: Choose source as AIR SPY R2/ Mini


Step 3: Start receiving the strongest signal


RESULT:
A nearby FM station is received

Signature Not Verified
Principal.VJEC

## VIMAL JYOTHI ENGINEERING COLLEGE



DEPARTMENT OF CIVIL ENGINEERING ENVIRONMENTAL ENGINEERING LABORATORY MANUAL

## CEL 411

(As per KTU syllabus)
For Fourth Year B.Tech Civil Engineering Students
ACADEMIC YEAR -2023-2024

## ENVIRONMENTAL

## ENGINEERING LABORATORY

## DEPARTMENT OF CIVIL ENGINEERING

Name of student : $\qquad$

PNR No. Roll No.

Semester \& Batch: $\qquad$

Branch :

# ENVIRONMENTAL ENGINEERING LABORATORY RECORD 

For Fourth Year B.Tech Degree Course<br>(As per the APJ Abdul Kalam Technological University Syllabus)

Name $\qquad$
PRN No Roll No

Semester \& Branch $\qquad$
University Reg. No $\qquad$

## CERTIFICATE

Certified that this is the bonafide record of the work done in the Environmental Engineering Laboratory of Vimal Jyothi Engineering College, Chemperi, Kannur under APJ Abdul Kalam Technological University by

Mr./Ms. $\qquad$
during the year $\qquad$

Place

Date

> Staff in charge

Head of the Department

# VIMAL JYOTHI ENGINEERING COLLEGE JYOTHI NAGAR, CHEMPERI, KANNUR - 670632 

www.vjec.ac.in

## Vision

To bloom into a Center of Excellence for Technical Education and a pacesetter in rural India with its quality processes and procedure, interwoven with freedom of flexibility, moulding professionals of superior quality, dedicated to the progress and development of Humanity.

## Mission

To prepare the students to see beyond geographical limit and belong to a new age of acquisition and application of technology to meet the challenges of the changing world. Inspired and guided by gospel values, we contribute to socioeconomic welfare of the country with due concern to the marginalized.

## Quality Policy

VJEC is committed to provide quality education in engineering and technology, to transform the youth into committed technical personal for the social and economic wellbeing of the nation with integral development of the personality and character building.

## Motto

"Where Perfection is the Tradition"

## DEPARTMENT Of CIVIL ENGINEERING

## Vision

To develop into a center of excellence for quality education moulding competent civil engineering professionals dedicated to the progress and development of humanity.

## Mission

- To provide quality education and training to create competent civil engineers.
- To interact with industries to provide a knowledge base for existing and emerging technologies in the field of civil engineering.
- To inculcate moral and ethical values among the students to mould them as civil engineers with social obligations.


## Program Educational Objectives (PEOs)

PEO1: Graduates will acquire the knowledge in civil engineering to achieve successful career as a civil engineering professional or entrepreneur, to analyze the practical problem and think creatively to generate innovative solutions using appropriate technologies.

PEO2: Graduates will make valid judgment, synthesize information from a range of sources and communicate them in sound ways appropriate to their discipline.

PEO3: Graduates will sustain intellectual curiosity and pursue lifelong learning not only in areas that are relevant to Civil engineering, but also that are important to society.

PEO4: Graduates will adapt to different roles and demonstrate leaderships in global working environment by respecting diversity, professionalism and ethical practices.

## Program Outcomes (POs)

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

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

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

PO4: Conduct Investigations of Complex Problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations. Signature Not Verified

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

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

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

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

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

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

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

## Program Specific Outcome (PSOs)

PSO1: Graduates will have the ability to design a civil engineering system or process to meet the desired needs of the society.

PSO1: Graduates will have the ability to design and conduct experiments in various areas of civil engineering as well as analyze and interpret data.

CIVIL ENGINEERING

| CEL411 | ENVIRONMENTAL ENGG | CATEGORY | L | T | P | CREDIT | YEAR OF |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| LABTRODUCTION |  |  |  |  |  |  |  |

Preamble: This lab provides the knowledge on tests used to analyse the physio-chemical and bacteriological properties of water and explains the various method followed in the test along with its suitability as a drinking water.

Prerequisite: CET 304 Environmental Engineering
Course Outcomes: After the completion of the course, the student will be able to:

| Course <br> outcome | Description |
| :---: | :--- |
| $\mathbf{C O 1}$ | Analyse various physico-chemical and biological parameters of water |
| $\mathbf{C O 2}$ | Compare the quality of water with drinking water standards and recommend its <br> suitability for drinking purposes |

## Mapping of course outcomes with program outcomes:

|  | PO <br> $\mathbf{1}$ | $\mathbf{P O 2}$ | $\mathbf{P O}$ <br> $\mathbf{3}$ | $\mathbf{P O}$ <br> $\mathbf{4}$ | $\mathbf{P O}$ <br> $\mathbf{5}$ | $\mathbf{P O}$ <br> $\mathbf{6}$ | $\mathbf{P O}$ <br> $\mathbf{7}$ | $\mathbf{P O}$ <br> $\mathbf{8}$ | $\mathbf{P O}$ <br> $\mathbf{9}$ | $\mathbf{P O 1 0}$ | $\mathbf{P O 1 1}$ | $\mathbf{P O 1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{C O 1}$ | 3 | 3 | 3 | 1 | - | 3 | 3 | - | - | - | - | 3 |
| $\mathbf{C O 2}$ | 3 | 3 | 3 | 1 | - | 3 | 3 | - | - | - | - | 3 |

## Assessment Pattern:

Mark distribution

| Total marks | CIE | ESE | ESE Duration |
| :---: | :---: | :---: | :---: |
| 150 | 75 | 75 | 3 Hrs |

CIVIL ENGINEERING

## Continuous Internal Evaluation (CIE) Pattern:

| Attendance | $: 15$ marks |
| :--- | :--- |
| Continuous Assessment | $: 30$ marks |
| Internal Test | $: 30$ marks |

## End Semester Examination (ESE) Pattern:

The following guidelines should be followed regarding award of mark
(a) Preliminary work
: 15 Marks
(b) Implementing the work/Conducting the
: 10 Marks
experiment
(c) Performance, result and inference (usage of equipment and trouble shooting) : 25 Marks
(d) Viva voce
: 20 Marks
(e) Record
: 5 Marks

CIVIL ENGINEERING

## Instructions:

- Any 12 of the 18 experiments included in the list of experiments need to be performed mandatorily.
- Virtual Lab facility cannot be used to substitute the conduct of these mandatory experiments.
- Periodic maintenance and calibration of various testing instruments needs to be made.
- Practical examination to be conducted covering entire syllabus given below. Evaluation is to be conducted under the equal responsibility of both the internal and external examiners. Students shall be allowed for the University examination only on submitting the duly certified record. The external examiner shall endorse the record.


## Syllabus

1. Determination of pH , Electrical Conductivity and Turbidity*
2. Determination of TS, TDS and TSS, TVS *
3. Determination of Alkalinity and Acidity *
4. Determination of Hardness *
5. Determination of Chlorides
6. Determination of Total Iron
7. Determination of Biochemical Oxygen Demand*
8. Determination of Chemical Oxygen Demand*
9. Optimum Coagulant dosage*
10. Break point Chlorination *
11. Determination of Available Chlorine in a sample of bleaching powder
12. Determination of Sulphates
13. Determination of Fluoride
14. Determination of Dissolved Oxygen*
15. Determination of nitrates
16. Determination of phosphates
17. Determination of any two Heavy Metal concentration

CIVIL ENGINEERING
18. Total coliforms *

Note: * mandatory

## References

1. Standard Methods for the Examination of Water and Wastewater, $23^{\text {rd }}$ edition, American Public Health Association, American Water Works Association, Water Environment Federation, 2017
2. Water Supply Engineering, $33^{\text {rd }}$ edition, Santhosh Kumar Garg, Khanna publishers.
3. Sewage Disposal and Air Pollution Engineering, $39^{\text {th }}$ edition, Santhosh Kumar Garg, Khanna publishers.
4. IS: 10500:2012 Drinking Water - Specification, Second revision, Bureau of Indian Standards, 2012.

## Guidelines to Students

1. In the very beginning of the laboratory work, the students will be organized into groups.
2. Every laboratory session is divided into two parts. In the first part, the Faculty in charge will be lecturing on the test objective, procedure and data collection. In the second part, the students, organized in groups, are required to conduct the laboratory work.
3. In order to perform the laboratory work within the assigned period, and to gain the maximum benefit from the laboratory work, the students must familiarize themselves with the purpose, objective, and procedure of the experiment before coming to the laboratory.
4. Relevant lecture notes and laboratory manual should be studied carefully and thoroughly.
5. At the end of the test, every group should submit a draft sheet of the data collected for approval by the faculty.
6. The instruments and tools must be properly cared and cleaned during and after every laboratory

Rubrics for Evaluation

| Category | Excellent <br> Above 80\% | $\begin{gathered} \text { Good } \\ \mathbf{6 1 \% - 8 0 \%} \end{gathered}$ | Satisfactory Below 60\% |
| :---: | :---: | :---: | :---: |
| Punctuality, Dress code \& Guidelines (5 Marks) | Entering lab beforete commencement of class and with all dress code according to the guide lines (Full time) | Entering lab after starting the class with a reasonable excuse. <br> Entering lab with all dress code according tithe guide lines (Partially) | Entering lab after starting the class without reasonable excuse. Dressed inappropriately and/or unkempt. |
| Knowledge of Theory (5 Marks) | The purpose of the lab or the question to be answered during the lab is clearly identified and stated. | The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner. | The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant. |
| Conduction (5 Marks) (For experiments only) | Used time pretty well. Stayed focused on the experiment most of the time. Usually provides useful ideas when participating in the group and in classroom discussion. | Did the lab but did not appear very interested. Sometimes provides useful ideas when participating in the group and in classroom discussion. | Participation was minimal OR student was hostile about participating. Rarely provides useful ideas when participating in the group and in classroom discussion. |
| Calculation (5 <br> Marks) <br> (For experiments only) | Actively looks for and suggests solutions to problems. | Does not suggest or refine solutions, but is willing to try out solutions suggested by others. | Does not try to solve problems or help others solve problems. Lets others do the work. |
| Result (5 Marks) (For experiments only) | Results with $90 \%$ above accuracy from the class itself | Results with 80-89\% accuracy from the class itself. | Results with below 80\% accuracy from the class itself. |
| Viva <br> (5 Marks Experiment) | Student demonstrates full knowledge by answering all questions with explanations | Student is uncomfortable with information and is able to answer only rudimentary questions. | Student does not have grasp of information; student cannot answer questions about subject |

$\qquad$

## 1. DETERMINATION OF $\mathbf{p H}$, TURBIDITY AND CONDUCTIVITY

## (i) pH :

It is the positive Hydrogen ion concentration. The pH scale is used to express the concentration of hydrogen ions in a liquid. The pH scale ranges from 1 to 14 i.e. most acid to most alkaline. The hydrogen ion concentration is an important parameter in determining the quality of water and wastewater. The pH of the water/wastewater sample is measured by pH meter. A pH meter consists of a measuring probe connected to electronic meter that measures and displays the pH reading.

## Environmental significance:

Determination of pH is one of the important objectives in biological treatment of the wastewater. In anaerobic treatment, if the pH goes below 5 due to excess accumulation of acids, the process is severely affected. Shifting of pH beyond 5 to 10 upsets the aerobic treatment of the wastewater. In these circumstances, the pH is generally adjusted by addition of suitable acid or alkali to optimize the treatment of the wastewater. pH value or range is of immense importance for any chemical reaction. Chemical coagulation, disinfection, water softening and corrosion control are governedby pH adjustment.

Lower value of pH below 4 will produce sour taste and higher value above 8.5 a bitter taste. Higher values of pH hasten the scale formation in water heating apparatus and also reduce the germicidal potential of chlorine.

## Aim:

To determine the pH of the given water sample.

## Principle:

The pH electrode used in the pH measurement is a combined glass electrode. It consists of sensing half-cell and reference half-cell, together form an electrode system. The sensing half-cell is a thin pH sensitive semi permeable membrane, separating two solutions, viz., the outer solution, the sample to be analyzed and the internal solution enclosed inside the glass membrane and hat has atifed known pH value. An electrical potential is developed inside and another electrical potentia ${ }^{1}$

Observations and calculations:

| Sample No. | $\mathbf{p H}$ |  |
| :--- | :--- | :--- |
|  | $\mathbf{p H}$ meter | $\mathbf{p H}$ paper |
|  |  |  |
|  |  |  |
|  |  |  |

developed outside, the difference in the potential is measured and is given as the pH of the sample.

## Apparatus:

pH meter, Beaker.

## Procedure:

1. Rinse the probe with distilled water. Calibrate the pH meter using reference solution.
2. Rinse the probe with the sample and dip the pH measuring probethe in sample and read the value of pH on the screen of the pH meter.
3. Rinse the probe with distilled/deionized water between samples.
4. Thoroughly rinse the probe in distilled water after measurement, keep it in distilled water when not in use.

## (ii) Turbidity:

Turbidity is a measure of suspended matter that affects the light scattering /light absorption properties of water. Jackson (light absorption principle) and Nephelometric (intensity light scattering principle) meters are mostly used to measure turbidity of water samples. The units of turbidity are Jackson turbidity unit (JTU) and Nephelometric turbidity unit (NTU).

## Environmental significance:

Knowledge of the turbidity variation in raw water supplies is useful to determine whether a supply requires special treatment by chemical coagulation and filtration before it may be used for a public water supply. Turbidity measurements are

## Observation and Calculations

| Sample | Turbidity (NTU) |
| :---: | :---: |
| 1 |  |
| 2 |  |

used to determine the effectiveness of treatment produced with different chemicals and the dosages needed. Turbidity measurements help to gauge the amount of chemicals needed from day-to-day operation of water treatment works. Measurement of turbidity in settled water prior to filtration is useful in controlling chemical dosages so as to prevent excessive loading of rapid sand filters. Turbidity measurements of the filtered water are needed to check on faulty filter operation. Turbidity measurements are useful to determine the optimum dosage of coagulants to treat domestic and industrial wastewaters. Turbidity determination is used to evaluate the performance of water treatment.

## Aim:

To determine the turbidity of the given water sample.

## Principle:

Turbidity is measured photo-metrically by determining the percentage of light of a given intensity is scattered or absorbed.

## Apparatus:

Turbidity meter; sample tubes

## Reagents:

Reference standard turbidity solutions ( $0.2,10$ and 1000 NTU)

## Procedure:

1. Switch on turbidity meter and wait for few minutes till the instrument warms up.
2. Shake the standard solution present in the cell/bottle before keeping it in sample chamber/holder and measure the turbidity of the reference standard solutions.
3. Any deviation in reading of the reference solution, calibrate the instrument using calibration switch.
4. Shake the sample before keeping it in sample chamber/holder and note down the turbidity of the sample.

## (ii) Electrical Conductivity:

The electrical conductivity (EC) is a measure of the capacity of a substance or solution to carry an electrical current. The conductivity is represented by reciprocal value of electrical resistance in ohms relative to cubic centimeter of water at $25^{\circ} \mathrm{C}$. The measured EC value is used as an alternate method to estimate the total dissolved solids (TDS) concentration of the sample. EC is represented by the symbol ' k ' and its units are milli siemens per meter ( $\mathrm{mS} / \mathrm{m}$ ) or micro mhos per centimeter [ $\mu \mathrm{mho} / \mathrm{cm}$ ].

## Environmental significance:

Measuring conductivity is a quick and easy way to estimate the amount of total dissolved solids (TDS) in natural waters, since most of these solids dissolve to form ions. Whereas total dissolved solids can include organic as well as inorganic molecules, conductivity depends only upon dissolved ions. Conductivity measurements can also be a useful tool for monitoring the inflow of saline water in estuaries and identifying sources of pollution, such as mining or industrial waste or agricultural runoff.

Municipal water supplies are monitored for conductivity, as increased dissolved solids in the water supply can create hard water, add scale build-up to plumbing, and change the taste of the water.

## Aim:

To determine the turbidity of the given water sample.

## Principle:

Conductivity is determined using the distance between the electrodes and their surface area. According to Ohm's law, the current through a conductor between two points is directly proportional to the potential difference across the two points.

## Apparatus:

Conductivity meter, small beakers

## Calculations:

The conductance ( G in $\mu \mathrm{mho}$ ) of standard potassium chloride $(\mathrm{KCl})$ solution is measured and from the corresponding conductivity, a cell constant ' C ' is calculated by the expression:

$$
C=\frac{k}{G}
$$

For 0.01 N KCl solution the ' $k$ ' value is 1412 .

$$
E C=G_{s} * C(\mu \mathrm{mho} / \mathrm{cm})
$$

where $G_{s}=$ measured conductance of the given sample.
The TDS of an unknown sample is calculated using the following relationship:

$$
T D S(\mathrm{mg} / \mathrm{l})=C \times E C(\mu \mathrm{mho} / \mathrm{cm})
$$

where C is empirical constant (it varies between 0.55 to 0.9 , depending upon the soluble solids present in water).

## Reagent:

Distilled water or deionized water: The water should have an electrical conductivity of less than $0.01 \mathrm{mS} / \mathrm{m}(<0.1 \mu \mathrm{mho} / \mathrm{cm})$. Boil the water shortly before use to minimize $\mathrm{CO}_{2}$ content (equal to atmospheric equilibrium).
0.01 M Standard potassium chloride solution (KCl): Dissolve 745.6 mg anhydrous KCl (dried 1 hour at $180^{\circ} \mathrm{C}$ ) in conductivity water and dilute to 1000 ml . This solution has an electrical conductivity of $141.2 \mathrm{mS} / \mathrm{m}$ at $25^{\circ} \mathrm{C}$.

## Procedure:

1. Rinse conductivity cell with 0.01 M KCl solution. Calibrate the conductivity meter using the KCl reference solution to obtain cell constant.
2. Measure the electrical conductivity of the 0.01 M KCl solution at room temperature
3. Rinse cell with sample and measure the electrical conductivity of the sample.
4. Rinse the cell with deionized water between samples.
5. Thoroughly rinse the cell in distilled water after measurement, keep it in distilled water when not in use.

## Result

pH =
Turbidity =
Conductivity =

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: $\qquad$ / 30

Dated signature of Faculty:

Date: $\qquad$

## 2. DETERMINATION OF ACIDITY AND ALKALINITY

## (i) Aciditv:

Acidity is the measure of the amount of base required to neutralize a given sample to the specific pH . Strong mineral acids, weak acids such as carbonic, acetic and hydrolyzing salt such as ferric and aluminium sulphates may contribute acidity. It is important because acid contributes to corrosiveness and influences certain chemical and biological processes. Dissolved $\mathrm{CO}_{2}$ is usually the major acidity component of unpolluted surface water. In the sample, containing only carbon dioxide-bicarbonate carbonate, titration to pH 8.3 at $25^{\circ} \mathrm{C}$ corresponds to stoichiometric neutralisation of carbonic acid to carbonate. Since the colour change of phenolphthalein indicator is close to pH 8.3 , this value is accepted as a standard end point for the titration of total acidity. For more complex mixture or buffered solution fixed end point of pH 3.7 and pH 8.3 are used. Thus, for standard determination of acidity of wastewater and natural water, methyl orange acidity ( pH 3.7 ) and phenolphthalein acidity ( pH 8.3 ) are used.

## Environmental significance:

Acid waters are of concern because of their corrosive characteristics and the expense involved in removing or controlling the corrosion-producing substances. The corrosive factor in most waters is carbon dioxide, but in many industrial wastes it is mineral acidity. Carbon dioxide must be reckoned with in watersoftening problems where the lime or lime-soda ash method is employed. When biological processes of treatment are used, the pH must ordinarily be maintained within the range of 6 to 9.5 . This criterion often requires adjustment of pH to favorable levels, and calculation of the amount of chemicals needed is based upon acidity values in most cases

## Observations and calculations

1. Burette solution: NaOH
2. Pipette solution: Sample
3. Indicator: Methyl orange, Phenolphthalein
4. End Point: Yellow, Pink

| Sample | Volume of Sample <br> (ml) | Burette reading |  | Volume of NaOH <br> $(\mathbf{m l})$ |
| :--- | :---: | :---: | :---: | :---: |
|  |  | Initial reading <br> $(\mathbf{m l})$ | Final reading <br> $(\mathbf{m l})$ |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Methyl orange acidity due to mineral acids $($ as CaCO 3$)=(\mathrm{V} 1 * \mathrm{~N}$ of $\mathrm{NaOH} * 50,000)$
Vol. of Sample

Phenolphthalein acidity $=$ Total acidity (as CaCO3)

$$
=(\underline{\mathrm{V} 2 * \mathrm{~N} \text { of } \mathrm{NaOH} * 50,000})
$$

Vol. of Sample
$\mathrm{V} 1=$ Volume of NaOH consumed when color changes from orange red to yellow(Mineral acidity)
$\mathrm{V} 2=$ Volume of NaOH consumed for total acidity

## Aim:

To determine the acidity in the given water and waste water samples.

## Principle:

Hydrogen ions present in a sample as a result of dissociation or hydrolysis of solutes are neutralised by titration with standard alkali. The acidity thus depends upon the end point pH or indicator used.

## Apparatus:

Burette, Pipette, conical flasks, measuring cylinder, volumetric flasks and beakers.

## Reagents

0.02 N NaOH Solution: Dissolve 0.8 g of NaOH in distilled water and dilute to 1000 ml Methyl orange indicator: Dissolve 50 g of methyl orange powder in distilled water and dilute to 100 ml

Phenolphthalein indicator: Dissolve 1 g of phenolphthalein in 100 ml of $95 \%$ ethyl alcohol or isopropyl alcohol, and add 100 ml of distilled to it and 0.02 N NaOH solution drop wise until faint pink colour appears.

## Procedure

1 Pipette out 25 mL of sample into conical flask. Add 2 drops of methyl orange indicator to the sample solution. The solution turns orange red
2 Titrate the sample solution against 0.02 N sodium hydroxide solution. The end point is noted when the colour changes from orange red to yellow.

3 Add two drops of phenolphthalein indicator and continue the titration till a pink colour formation. Note down the volume of the titrant used.

## (ii) Alkalinitv:

The alkalinity of water is a measure of its capacity to neutralize acids i.e. to absorb hydrogen ions, without significant pH change. The alkalinity in water is primarily due to the presence of salts of weak acids and strong bases. It is caused by presence of hydroxides $\left(\mathrm{OH}^{-}\right)$, carbonates $\left(\mathrm{CO}^{--}\right)$and bicarbonates $\left(\mathrm{HCO}_{3}\right)$.

## Environmental significance:

Wastewaters containing excess caustic (hydroxide) alkalinity are not to be discharged into natural water bodies or sewers. Alkalinity as carbonate and bicarbonate of saline water is very important in tertiary recovery processes for recovering petroleum. Alkaline water offers better wetting to the formation rock and improve oil release. As an additional benefit, ions that provide alkalinity absorb on rock surfaces occupying adsorption sites and decrease the loss of recovery chemical by adsorption. The alkalinity value is necessary in the calculation of carbonate scaling tendencies of saline waters.

The alkalinity acts as a pH buffer in coagulation and lime-soda softening of water. In wastewater treatment, alkalinity is an important parameter in determining the amenability of wastes to the treatment process and control of processes such as anaerobic digestion, where bicarbonate alkalinity, total alkalinity, and any fraction contributed by volatile acid salts become considerations.

## Aim:

To determine the alkalinity of given water sample

## Principle:

Alkalinity can be obtained by neutralizing $\mathrm{OH}^{-}, \mathrm{CO}^{2-}$ and $\mathrm{HCO}^{-}$with standard $\mathrm{H}_{2} \mathrm{SO}_{4}$. Titration to pH 8.3 or decolourisation of phenolphthalein indicator will show complete neutralization of $\mathrm{OH}^{-}$and $1 / 2 \mathrm{CO}_{3}{ }^{2}$, while to pH 4.4 or sharp change from yellow to pink of methyl orange indicator will indicate total alkalinity

## Observations and Calculations

## Titration 1 (For Phenolphthalein alkalinity)

Burette solution: $\mathrm{H}_{2} \mathrm{SO}_{4}$
Pipette solution: Sample
Indicator: phenolphthalein
End Point: Disappearance of pink colour

| Sample <br> No. | Volume of Sample <br> $(\mathrm{ml})$ | Burette reading |  | Volume of $\mathrm{H}_{2} \mathrm{SO}_{4}$ <br> $(\mathrm{ml})$ |
| :--- | :---: | :---: | :---: | :---: |
|  |  | Initial reading <br> $(\mathrm{ml})$ | Final reading <br> $(\mathrm{ml})$ |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

## Titration 2 (For total alkalinity)

Burette solution: $\mathrm{H}_{2} \mathrm{SO}_{4}$
Pipette solution: Sample
Indicator: mixed indicator (methyl orange)
End Point: Appearance of pink colour (yellow to pink)

| Sample <br> No. | Volume of Sample <br> $(\mathrm{ml})$ | Burette reading |  | Volume of H2SO4 <br> $(\mathrm{ml})$ |
| :--- | :---: | :---: | :---: | :---: |
|  |  | Initial reading <br> $(\mathrm{ml})$ | Final reading <br> $(\mathrm{ml})$ |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Phenolphthalein alkalinity $(\mathrm{P})\left(\right.$ as $\left.\mathrm{CaCO}_{3}\right)=\left(\mathrm{V} 1 * \mathrm{~N}^{2} \mathrm{Hf}_{2} \mathrm{SO}_{4} * 50,000\right)$
Vol. of sample.

Total alkalinity $(\mathrm{T})\left(\mathrm{as}_{\mathrm{CaCO}}^{3}\right)=\left(\mathrm{V} 2 * \mathrm{~N}^{2}\right.$ of $\left.\mathrm{H}_{2} \mathrm{SO}_{4} * 50,000\right)$
Vol. of sample

$$
\begin{gathered}
\mathrm{Ca}(\mathrm{OH})_{2}+\mathrm{H}_{2} \mathrm{SO}_{4} \rightarrow \mathrm{CaSO}_{4}+2 \mathrm{H}_{2} \mathrm{O} \\
2 \mathrm{CaCO}_{3}+\mathrm{H}_{2} \mathrm{SO}_{4} \rightarrow \mathrm{Ca}\left(\mathrm{HCO}_{3}\right)_{2}+\mathrm{CaSO}_{4} \\
\mathrm{Ca}\left(\mathrm{HCO}_{3}\right)_{2}+\mathrm{H}_{2} \mathrm{SO}_{4} \rightarrow \mathrm{CaSO}_{4}+\mathrm{CO}_{2}
\end{gathered}
$$

## Apparatus:

Burettes, volumetric flasks, conical flasks, measuring cylinder and beakers.

## Reagents:

0.05N Standard sodium carbonate solution: Dry 3 to 5 g of sodium carbonate, $\mathrm{Na}_{2} \mathrm{CO}_{3}$, at $250^{\circ} \mathrm{C}$ for 4 hour and cool in a dessicator. Accurately weigh $2.5 \pm 0.2 \mathrm{~g}$ to the nearest mg , dissolve in distilled water and make to 1L.
0.1N Standard H2SO4 solution: Dilute 2.8 mL conc. sulphuric acid to 1L. Standardise against 40.00 mL 0.05 N Na 2 CO 3 with about 60 mL distilled water, in a beaker by titrating potentiometrically to pH 5 . Lift out electrodes, rinse into the same beaker and boil gently for 3 to 5 min under a watch glass cover. Cool to room temperature, rinse cover glass into beaker and finish titration to pH 4.3 . Calculate normality of sulphuric acid:
Normality, $N=\frac{(A \times B)}{(53.00 \times C)}$
where:
$\mathrm{A}=\mathrm{g} \mathrm{Na}_{2} \mathrm{CO}_{3}$ weighed into the 1 L -flask for the $\mathrm{Na}_{2} \mathrm{CO}_{3}$ standard
$\mathrm{B}=\mathrm{mL} \mathrm{Na}_{2} \mathrm{CO}_{3}$ solution taken for standardisation titration
$\mathrm{C}=\mathrm{mL}$ acid used in standardisation titration
0.02 $N$ Standard sulphuric acid solution: Dilute the approximate 0.1 N solution to

1L. Calculate volume to be diluted as:
Volume (ml) $=\mathrm{N} / 20$
where: $\mathrm{N}=$ exact normality of the approximate 0.1 N solution

Phenolphthalein indicator solution (alcoholic, pH 8.3) - Dissolve 5 g phenolphthalein in 500 mL of $95 \%$ ethyl alcohol. Add 500 mL distilled water

Mixed indicator (Methyl Orange Indicator) - Dissolve 20g of methyl red, 100mg of bromocrysol green in 100 $\mathrm{ml} 95 \%$ ethyl or isopropyl alcohol.

## Procedure:

## Phenolphthalein alkalinity:

1. Take 25 to 50 mL sample in a conical flask.
2. Add 2 to 3 drops of phenolphthalein indicator. If it turns pink $(\mathrm{pH}>8.3)$, titrate with $0.02 \mathrm{~N} \mathrm{H}_{2} \mathrm{SO}_{4}$ till the pink colour disappear. Record volume (mL) of titrant used.

## Total alkalinity:

1. Add a drop of mixed indicator to the solution in which the phenolphthalein alkalinity is determined. The solution turns blue
2. Titrate it against 0.02 N sulphuric acid. Appearance of red colour indicates the end point.

## Result

(i) Methyl orange acidity =

Phenolphthalein acidity =
Total acidity =
(ii) Total alkalinity present in the water sample $=$ Phenolphthalein alkalinity present in the sample $=$ Methyl orange alkalinity present in the sample $=$

## Inference

Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks:
/ 30

Dated signature of Faculty:

## 3. DETERMINATION OF CHLORIDES

## Chlorides:

Chlorides are present in water and wastewater in varying concentration. Various sources such as mineral contents, sea water droplets, human excreta discharging to natural water bodies contribute chloride concentration to water.

## Environmental significance:

Chlorides in reasonable concentrations are not harmful to human. At concentrations above $250 \mathrm{mg} / \mathrm{L}$ they give a salty taste to water, which is objectionable to many people. For this reason, chlorides are generally limited to $250 \mathrm{mg} / \mathrm{L}$ in supplies intended for public use. In many areas of the world where water supplies are scarce, water source containing as much as $2,000 \mathrm{mg} / \mathrm{L}$ are used for domestic purposes without the development of adverse effects, once the human system becomes adapted to the water.

## Aim:

To determine the chloride concentration present in given water sample.

## Principle:

Chloride ion concentration in the water can be determined by titration with silver nitrate. As the silver nitrate solution is slowly added, a precipitate of silver chloride forms.

$$
\mathrm{Ag}^{+}(\mathrm{aq})+\mathrm{Cl}^{-}(\mathrm{aq}) \rightarrow \mathrm{AgCl}(\mathrm{~s})
$$

The end point of the titration occurs when all the chloride ions are precipitated. Then additional silver ions react with the chromate ions of the indicator, potassium chromate, to form a red-brown precipitate of silver chromate.

$$
2 \mathrm{Ag}^{+}(\mathrm{aq})+\mathrm{CrO}_{4}{ }^{2-}(\mathrm{aq}) \rightarrow \mathrm{Ag}_{2} \mathrm{CrO}_{4}(\mathrm{~s})
$$

Titration should be carried out under conditions of $\mathrm{pH} 6.5-9$. At higher pHy sil Ner . Verified ions may be removed by precipitation with hydroxide ions, and at low pH chromate ion

## Observations and calculations:

| Trial | Volume of $\mathrm{AgNO}_{3}(\mathrm{~mL})$ |  |  |
| :---: | :---: | :---: | :---: |
|  | Initial Reading <br> (IR) | Final Reading <br> (FR) | FR-IR |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Chloride in $\mathrm{mg} / \mathrm{l}=\left\{(\mathrm{V} 1-\mathrm{V} 2) * \mathrm{~N}\right.$ of $\left.\mathrm{AgNO}_{3} * 35.45^{*} 1,000\right\}$
Vol. of sample
may be removed by an acid-base reaction to form hydrogen chromate ions or dichromate ions, affecting the accuracy of the end point.

## Apparatus:

Burette, pipettes, conical flasks, beakers, measuring cylinders, weighing balance, stirrer etc.

## Reagents:

Indicator 5\% $\mathbf{K}_{2} \mathbf{C r O}_{4}: 1.0 \mathrm{~g}$ of $\mathrm{K}_{2} \mathrm{CrO}_{4}$ dissolved in 20 mL of distilled water.
$\boldsymbol{A g N O}_{3}$ solution: 9.0 g of $\mathrm{AgNO}_{3}$ was weighed out, transferred to a 500 mL volumetric flask and made up to volume with distilled water. The resulting solution was approximately 0.1 M .

## Procedure

1. Take 25 ml of sample in the conical flask. Adjust the sample pH between to be 7 to 8 by adding sulphuric acid or sodium hydroxide solution.
2. Add 1 ml of potassium chromate to get light yellow color.
3. Titrate with standard silver nitrate $\left(\mathrm{AgNO}_{3}\right)$ solution till the color changes from yellow to brick red. Note down the volume of $\mathrm{AgNO}_{3}$ solution added (V1).
4. Repeat the above procedure for the blank sample (distilled water) and note down the volume of $\mathrm{AgNO}_{3}$ solution added (V2).

## Result

(i) Chloride concentration in the given sample $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:
$\qquad$

## 4. DETERMINATION OF DISSOLVED OXYGEN (DO)

Dissolved oxygen is one of the most important constituents of natural water system. It indicates the pollution status of river. The dissolved oxygen in water depends upon its temperature and solubility. If DO is less, then it indicates the presence of organic matter. At least $4 \mathrm{mg} / \mathrm{l}$ of DO is required for fish and other species for survival.

## Environmental significance:

Adequate dissolved oxygen is necessary for good water quality. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below $4.0 \mathrm{mg} / \mathrm{l}$, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below $1-2 \mathrm{mg} / \mathrm{l}$ for a few hours can result in large fish kills.

## Aim:

To determine the amount of dissolved oxygen present in the given sample

## Principle:

It is based on the principle that oxygen present in the sample oxidizes the divalent manganous to its higher valency under alkaline conditions and that manganese in higher state of valencies is capable of oxidizing $\mathrm{I}^{-}$to $\mathrm{I}_{2}$ under acidic conditions. Thus the amount of $\mathrm{I}_{2}$ released is equivalent to the dissolved oxygen present. The iodine is measured with standard sodium thiosulphate solution.

If no oxygen is present, a pure white precipitate of $\mathrm{Mn}(\mathrm{OH})_{2}$ forms

$$
\mathrm{Mn}^{2+}+2 \mathrm{OH}^{-} \rightarrow \mathrm{Mn}(\mathrm{OH})_{2}(\mathrm{~s}) \text { (white ppt) }
$$

If oxygen is present

$$
\mathrm{Mn}^{2+}+2 \mathrm{OH}^{-}+\frac{1}{2} \mathrm{O}_{2} \rightarrow \mathrm{MnO}_{2}(\mathrm{~s})+\mathrm{H}_{2} \mathrm{O} \quad(\text { red ppt })
$$

Under low pH

$$
\mathrm{MnO}_{2}+2 \mathrm{I}^{-}+4 \mathrm{H}^{+} \rightarrow \mathrm{Mn}^{2+}+\mathrm{I}_{2}+2 \mathrm{H}_{2} \mathrm{O}
$$

$\mathrm{I}_{2}$ is rather insoluble in water, but forms a complex with the excess iodide present.

$$
\mathrm{I}_{2}+\mathrm{I}^{-} \leftrightarrow \mathrm{I}_{3}^{-}
$$

Thus more soluble tri-iodate prevents escape of $\mathrm{I}_{2}$ from the solution.

## Apparatus:

300 mL BOD bottles, burette, pipette, conical flask etc.,

## Reagents:

Manganous sulfate solution: Dissolve $480 \mathrm{~g} \mathrm{MnSO}_{4} 4 \mathrm{H}_{2} \mathrm{O}$, or $400 \mathrm{~g} \mathrm{MnSO} 4 \mathrm{MH}_{2} \mathrm{O}$, or $364 \mathrm{~g} \mathrm{MnSO}_{4} \mathrm{H}_{2} \mathrm{O}$ in distilled water, filter and dilute to 1 litre. This solution should not produce a blue color with starch indicator when added to an acidified potassium iodide (KI) solution.

Alkaline-iodide-sodium azide solution: Dissolve 500 g NaOH (or 700 g KOH ) and 135 g NaI (or 150 g KI ) in distilled water and dilute to IL. Add $10 \mathrm{~g} \mathrm{NaN}_{3}$ dissolved in 40 mL distilled water.

Starch indicator solution: Use either an aqueous solution or soluble starch powder mixture. Prepare an aqueous solution by dissolving 2 g of laboratory grade soluble starch powder and 0.2 g of salicylic acid (as a preservative) in 100 mL of hot distilled water.

Sodium thiosulfate standard solution, 0.025 N : Dissolve $6.205 \mathrm{~g} \mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3} 5 \mathrm{H}_{2} \mathrm{O}$ in distilled water. Add 1.5 mL 6 N NaOH or 0.4 g solid NaOH and dilute to 1 litre and standardize with bi-iodate solution.

## Procedure

1. Collect the sample to be tested in a 300 mL BOD bottle taking special care to avoid adding air to the liquid being collected. Fill bottle completely and add stopper.
2. Remove bottle stopper and add 2 mL of the manganous sulfate solution at the surface of the liquid. Add 2 mL of the alkaline-iodide-sodium azide solution at the surface of the liquid. Replace the stopper, avoid trapping air bubbles and shake well by inverting the bottle several times.
3. Repeat shaking after floc has settled halfway. Allow floc to settle a second time.
4. Add 2 mL of concentrated sulfuric acid and close the bottle with stopper. Rinse the Signature Not Verified top of the bottle to remove any acid and shake well until the precipitate is

## Observations and Calculations

The concentration of DO in the sample is calculated using the following formula:

$$
D O(\mathrm{mg} / \mathrm{l})=\frac{\mathrm{ml} \text { of titrant } * \text { normality of titrant } * 8000}{\text { volume of the sample titrated }}
$$

| Sl.No. | Burette reading of $\left(\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3} 5 \mathrm{H}_{2} \mathrm{O}\right)$ in ml |  | FR - IR |
| :--- | :--- | :--- | :--- |
|  | Initial reading (IR) | Final reading (FR) |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

completely dissolved (uniform yellow color)
5. Take 203 mL of sample from the BOD bottle into a conical flask and titrate with 0.0250 N sodium thiosulfate until the solution is a pale yellow (straw) color.
6. Add a small quantity (approximately 1 mL ) of starch indicator continue the titration with 0.0250 N sodium-thiosulfate until blue colour disappears (blue to colorless). Record the mL of sodium-thiosulfate used.

## Result

DO of the given sample $=$

## Inference:

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

Date: $\qquad$

## 5. DETERMINATION OF BIOLOGICAL OXYGEN DEMAND (BOD)

BOD is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under controlled aerobic conditions. The BOD test relies on measurable depletion of dissolved oxygen (DO) over a specified period of time, generally 5 days at $20^{\circ} \mathrm{C}$ incubation. The BOD is considered complete after 20 days. 20 Days is too long to wait and 5 days is a reasonable period as most of the BOD to be exerted is about 70 to $80 \%$ of total BOD.

## Environmental significance:

BOD is the principle test to give an idea of the biodegradability of any sample and strength of the waste. Hence the amount of pollution can be easily measured by it. Efficiency of any treatment plant can be judged by considering influent BOD and the effluent BOD and so also the organic loading on the unit.

Application of the test to organic waste discharges allows calculation of the effect of the discharges on the oxygen resources of the receiving water. Ordinary domestic sewage may have a BOD of $200 \mathrm{mg} / \mathrm{L}$. Any effluent to be discharged into natural bodies of water should have BOD less than $30 \mathrm{mg} / \mathrm{L}$. This is important parameter to assess the pollution of surface waters and ground waters where contamination occurred due to disposal of domestic and industrial effluents. Drinking water usually has a BOD of less than $1 \mathrm{mg} / \mathrm{L}$. But, when BOD value reaches $5 \mathrm{mg} / \mathrm{L}$, the water is doubtful in purity. The determination of BOD is used in studies to measure the self-purification capacity of streams and serves regulatory authorities as a means of checking on the quality of effluents discharged to stream waters.

## Aim:

To determine the BOD of the given sample

## Principle:

The BOD is measured by determining the oxygen consumed (by thesibatarerenot Verified from a sample placed in an air-tight container and kept in a controlled environment for

## Observations and calculations

## $0^{\text {th }}$ day reading

| Sample | Burette reading mL of $\left(\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3} 5 \mathrm{H}_{2} \mathrm{O}\right)$ |  |  |
| :--- | :--- | :--- | :--- |
|  |  |  |  |
|  | Final reading (FR) | Initial reading (IR) | FR-IR |
| Blank |  |  |  |
| BOD sample |  |  |  |

## 5 day reading

| Sample | Burette reading mL of $\left(\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3} 5 \mathrm{H}_{2} \mathrm{O}\right)$ |  |  | DO in mg/L |
| :--- | :--- | :--- | :--- | :--- |
|  | Final reading (FR) | Initial reading (IR) | FR-IR |  |
|  |  |  |  |  |
| BOD sample |  |  |  |  |

5 day $\mathrm{BOD}=\mathrm{BOD}_{5}(\mathrm{mg} / \mathrm{l})$

$$
=\frac{(D 1-D 2)-(B 1-B 2)}{P}
$$

$\mathrm{D} 1=\mathrm{DO}$ of the sample immediately after preparation, $\mathrm{mg} / \mathrm{L}$,
$\mathrm{D} 2=\mathrm{DO}$ of the sample after 5 day incubation at $20^{\circ} \mathrm{C}, \mathrm{mg} / \mathrm{L}$,
$\mathrm{B} 1=\mathrm{DO}$ of blank immediately after preparation, $\mathrm{mg} / \mathrm{L}$,
$\mathrm{B} 2=\mathrm{DO}$ of blank after 5 day incubation at $20^{\circ} \mathrm{C}, \mathrm{mg} / \mathrm{L}$,
$\mathrm{P}=$ dilution factor
a preselected period of time.

## Apparatus:

BOD bottles, burette, pipette, conical flask, BOD Incubator

## Reagents:

Phosphate buffer solution: Dissolve $8.5 \mathrm{~g} \mathrm{KH}_{2} \mathrm{PO}_{4}, 21.75 \mathrm{~g} \mathrm{~K}_{2} \mathrm{HPO}_{4}, 33.4 \mathrm{~g} \mathrm{Na}{ }_{2} \mathrm{HPO}_{4}$ $7 \mathrm{H}_{2} \mathrm{O}$, and 1.7 g NH 4 Cl in about 500 mL distilled water and dilute to 1 L . The pH should be 7.2 without further adjustment. Alternatively, dissolve $42.5 \mathrm{~g} \mathrm{KH}_{2} \mathrm{PO}_{4}$ or 54.3 g $\mathrm{K}_{2} \mathrm{HPO}_{4}$ in about 700 mL distilled water. Adjust pH to 7.2 with $30 \% \mathrm{NaOH}$ and dilute to 1 L .

Magnesium sulfate solution: Dissolve $22.5 \mathrm{~g} \mathrm{MgSO}_{4} 7 \mathrm{H}_{2} \mathrm{O}$ in distilled water and dilute to 1 L .

Calcium chloride solution: Dissolve $27.5 \mathrm{~g} \mathrm{CaCl}_{2}$ in distilled water and dilute to 1 L .
Ferric chloride solution: Dissolve $0.25 \mathrm{~g} \mathrm{FeCl}_{3} 6 \mathrm{H}_{2} \mathrm{O}$ in distilled water and dilute to 1 L . Dilution water: Place desired volume of distilled water in a suitable bottle and add 1 mL each of phosphate buffer, $\mathrm{MgSO}_{4}, \mathrm{CaCl}_{2}$, and $\mathrm{FeCl}_{3}$ solutions/L of water. Seed dilution water, if desired. pH of the dilution water should be between 6.5-8.5 (it is customary to buffer the solution by means of a phosphate system at about pH 7 ). Calcium and magnesium salts are added to give buffering capacity and proper osmotic conditions. Ferric chloride and magnesium sulphate supply the requirements for iron sulphur and nitrogen. The phosphate buffer furnishes any phosphorous that may be needed. The nitrogen should be eliminated in cases where nitrogenous oxygen demand is being measured.

## Procedure

1. Dilute the settled sewage provided to 30-40 times using aerated tap water.
2. Fill the BOD bottle with diluted sewage by taking care that no air bubble entraps.
3. Determine the DO of the BOD sample and blank.
4. Incubate both the sample and blank BOD bottles at $20^{\circ} \mathrm{C}$.
5.After 5 days take the bottles having sewage and blank from the incubator. 6. Measure DO and calculate $\mathrm{BOD}_{5}$.


Ultimate BOD, $\boldsymbol{L}_{\boldsymbol{t}}=\boldsymbol{L}_{\boldsymbol{o}}\left(\mathbf{1}-\boldsymbol{e}^{-\boldsymbol{k} t}\right)$
$\mathrm{L}_{\mathrm{t}}=\mathrm{BOD}$ at any time t
$\mathrm{L}_{0}=$ ultimate BOD
$\mathrm{T}=$ time in days
$\mathrm{K}=\mathrm{BOD}$ rate constant (0.23/day)

## Result

BOD of the given sample $=$
Ultimate BOD of the sample $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

Date: $\qquad$

## 6. DETERMINATION OF OPTIMUM COAGULATION DOSAGE

Coagulation is the process of destabilizing colloidal particles so that particle growth can occur as a result of particle collisions. In wastewater treatment, settleable solids are effectively removed by sedimentation process. But it is difficult to remove the small size colloidal particles by gravitational settling due to its Brownian motion. However, if the colloidal particles are destabilized through agglomeration of particles into group/large particles which increases the settling velocities, and thus can be effectively removed in sedimentation tank. The exact mechanism of coagulation is not known, however, four mechanisms are thought to be occurring during coagulation process. These include ionic layer compression, adsorption, charge neutralization and inter-particle bridging. Typical coagulants used in wastewater treatment are synthetic organic polymers, metal salts such as alum or ferric sulphate, prehydrolized metal salts (polyaluminum chloride and polyiron chloride).

## Environmental significance:

Coagulation of raw water using the optimum coagulant dose removes colloidal impurities from the water. These colloidal impurities are normally associated with organic matter containing pathogenic bacteria which are responsible for water borne diseases. The chemical coagulation also makes the process of disinfection more effective. Coagulation also removes objectionable colour, taste and odour from water. Usually the dose of Alum varies between $5 \mathrm{mg} / \mathrm{l}$ for relatively clear water to about $85 \mathrm{mg} / \mathrm{l}$ for very turbid waters. The average dose is about $20 \mathrm{mg} / \mathrm{l}$.

## Aim:

To find the optimum amount of coagulant required to treat given water sample.

## Principle:

Metal salts hydrolyse in presence of the natural alkalinity to form metal hydroxides. The divalent cations can reduce the zeta-potential, while the metal

## Observations and calculations

| Concentration (ppm) | Turbidity (NTU) |
| :--- | :--- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

hydroxides are good absorbents and hence remove the suspended particles by enmeshing them.

Alum $\left[\mathrm{Al}_{2} \mathrm{~S}\left(\mathrm{SO}_{4}\right)_{3} .18 \mathrm{H}_{2} \mathrm{O}\right]$ is the most widely used coagulant in water treatment. When alum solution is added to water, the molecules dissociate to yield $\mathrm{SO}_{4}{ }^{2-}$ and $\mathrm{Al}^{3+}$. The +ve species combine with negatively charged colloidal to neutralise part of the charge on the colloidal particle. Thus, agglomeration takes place.

Coagulation is a quite complex phenomenon and the coagulant should be distributed uniformly throughout the solution. A flash mix accomplishes this.

Apparatus: Jar test apparatus, turbid meter, beakers, pipette and pH meter.

## Reagents

Alum, Ferric chloride

## Procedure

1. Measure the initial turbidity of the given sample.
2. Find the pH of the sample and adjust it to 6 to 8.5 .
3. Take six jars of 11 capacity and take 0.51 of sample in each jar and add varying doses of alum $(1,2,4,6,8,10 \mathrm{mg} / \mathrm{l})$ of alum to each one of them.
4. Keep the sample in jar test apparatus and put it for rapid mixing at 100 rpm for 1 min and then to slow mixing at 20 rpm for 20 min .
5. Stop the motor and allow the sample to settle for 30 min . Collect the supernatant from each jar and find out the turbidity.
6. Plot a graph with alum dosage along x -axis and turbidity along y -axis.
7. The dosage of alum, which represents least turbidity, gives Optimum Coagulant Dosage (O.C.D.).
8. Repeat steps 3-6 with higher dose of alum, if necessary.


## Result

Optimum coagulant dosage $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:
Signature Not Verified

Date: $\qquad$

## 7. DETERMINATION OF AVAILABLE CHLORINE

Chlorination of public water supplies and polluted waters serves primarily to destroy or de-activate disease-producing microorganisms. Disinfection with chlorine is widely practiced. Chlorination may produce some adverse effects including taste and odor problem. in recent years, chlorination has been found to produce trihalomethanes (THMs) and other organics of health concern (THMs are suspected human carcinogens). Thus, use of alternative disinfectants, such as chlorine dioxide and ozone that do not cause this particular problem, is increasing.

## Environmental Significance:

Bleaching powder is commonly used as a disinfectant. The chlorine present in the bleaching powder gets reduced with time. So, to find the exact quantity of bleaching powder required, the amount of available chlorine in the sample must be found out. Chlorine will liberate free iodine from potassium iodide solution when its pH is 8 or less. The iodine liberated, which is equivalent to the amount of active chlorine, is titrated with standard sodium thiosulphate solution using starch as indicator.

## Aim:

To determine the available chorine in the bleaching powder.

## Principle:

Disinfectant capabilities of chlorine depend on its chemical form in water, which in turn is dependent on pH , temperature, organic content of water, and other water quality factors. Chlorine is used in the form of free chlorine [e.g., chlorine gas] or as hypochlorites [e.g., NaOCl and $\mathrm{Ca}(\mathrm{OC} 1)_{2}$ ]. Chlorine applied to water either as free chlorine or hypochlorite initially undergoes hydrolysis to form free chlorine consisting of aqueous molecular chlorine, hypochlorous acid and hypochlorite ion.

Chlorine gas rapidly hydrolyzes to hypochlorous acid according to:

$$
\mathrm{Cl}_{2}+\mathrm{H}_{2} \mathrm{O} \rightarrow \mathrm{HOCl}+\mathrm{H}^{+}+\mathrm{Cl}^{-}
$$

Aqueous solutions of sodium or calcium hypochlorite hydrolyze to:

$$
\begin{aligned}
\mathrm{Ca}(\mathrm{OCl})_{2}+2 \mathrm{H}_{2} \mathrm{O} & \longrightarrow \mathrm{Ca}^{2+}+2 \mathrm{HOCl}+2 \mathrm{OH}^{-} \\
\mathrm{NaOCl}+\mathrm{H}_{2} \mathrm{O} & \longrightarrow \mathrm{Na}^{+}+\mathrm{HOCl}+\mathrm{OH}^{-}
\end{aligned}
$$

Hypochlorous acid is a weak acid and will disassociate according to:

$$
\mathrm{HOCl} \Leftrightarrow \mathrm{H}++\mathrm{OCl}^{-}
$$

The two chemical species formed by chlorine in water, hypochlorous acid ( HOCl ) and hypochlorite ion $\left(\mathrm{OCl}^{-}\right)$, are commonly referred to as "free" or "available" chlorine.

## Apparatus:

Beakers, conical flasks, burette

## Reagents:

Standard chlorine solution, acetic acid, potassium iodide, 0.025 N standard sodium thiosulphate solution, iodine solution $(0.025 \mathrm{~N})$, starch indicator.

## Procedure:

1. Dissolve 1 g bleaching powder in 1 litre of distilled water in a volumetric flask, and stopper the container.
2. Place 5 mL acetic acid in an Erlenmeyer flask and add about 1 g potassium iodide crystals. Pour 25 mL of bleaching powder solution prepared above and mix with a stirring rod.
3. Titrate with 0.025 N sodium thiosulphate solution until a pale yellow colour is obtained. (Deep yellow changes to pale yellow.)
4. Add 1 mL of starch solution and titrate until the blue colour disappears.
5. Note down the volume of sodium thiosulphate solution added $\left(\mathrm{V}_{1}\right)$.
6. Take a volume of distilled water corresponding to the sample used.
7. Add 5 mL acetic acid, 1 g potassium iodide and 1 mL starch solution.
8. If blue colour occurs, titrate with 0.025 N sodium thiosulphate solution ugtigntuekelvot Verified colour disappears.

## Observations and Calculations:

Bleaching powder solution x Standard sodium thiosulphate solution ( 0.025 N )

| Sl. No. | Burette reading |  | Volume of the <br> titrant (ml) |
| :---: | :---: | :---: | :---: |
|  | Initial | Final |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Distilled water x Standard iodine solution (0.025N)

| Sl. No. | Burette reading |  | Volume of the <br> titrant (ml) |
| :---: | :---: | :---: | :---: |
|  | Initial | Final |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Distilled water $\times$ Standard sodium thiosulphate solution ( 0.025 N )

| Sl. No. | Burette reading |  | Volume of the <br> titrant (ml) |
| :---: | :---: | :---: | :---: |
|  | Initial | Final |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

$$
\left(\mathrm{V}_{1}-\mathrm{A}_{1}\right) \text { or }\left(\mathrm{V}_{1}+\mathrm{A}_{4}\right) \times \mathrm{N} \times 35.46
$$

mg of $\mathrm{Cl}_{2} / \mathrm{mL}(\mathrm{B})=\quad \mathrm{mL}$ of bleaching powder solution taken
1000 mL of bleaching powder solution contains $1000 \times \mathrm{Bmg}$ of $\mathrm{Cl}_{2}$ i.e., 1000 mg bleaching powder contains 1000 B mg of $\mathrm{Cl}_{2}$ therefore, 100 mg of bleaching powder contains $=\frac{1000 \times \mathrm{B}}{10}$
$\%$ of chlorine available $=$
9. Record the volume of sodium thiosulphate solution added $\left(\mathrm{A}_{1}\right)$.
10. If no blue colour occurs, titrate with 0.025 N iodine solution until a blue colour appears. Note down the volume of iodine $\left(\mathrm{A}_{2}\right)$.
11. Then, titrate with 0.025 N sodium thiosulphate solution till the blue colour disappears. Record the volume of sodium thiosulphate solution added ( $\mathrm{A}_{3}$ ). Note down the difference between the volume of iodine solution and sodium thiosulphate as $\mathrm{A}_{4}\left(\mathrm{~A}_{4}=\mathrm{A}_{2}-\mathrm{A}_{3}\right)$.

## Result:

The available chlorine in the given bleaching powder $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

Date: $\qquad$
ENVIRONMENTAL ENGINEERING LAB

## 8. DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD)

This test is used to measure the quantity of oxygen required to oxidize the organic material in wastewater using dichromate in an acid solution. COD test is widely used as a means of measuring the organic strength of domestic and industrial wastes. It allows measurement of a waste in terms of the total quantity of oxygen required for oxidation to $\mathrm{CO}_{2}$ and $\mathrm{H}_{2} \mathrm{O}$. The major advantage of COD test is the short time required for evaluation. Many organic matters which are difficult to oxidize biologically such as lignin can be oxidized chemically.

## Environmental Significance:

COD is often measured as a rapid indicator of organic pollutant in water; it is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. COD has further applications in power plant operations, chemical manufacturing, commercial laundries, pulp \& paper mills, environmental studies and general education.

## Aim:

To determine the Chemical oxygen demand (COD) of the given sample.

## Principle:

It is based on the principle that organic matter present in the sample gets oxidized completely by potassium dichromate $\left(\mathrm{K}_{2} \mathrm{Cr}_{2} \mathrm{O}_{7}\right)$ in the presence of sulphuric acid $\left(\mathrm{H}_{2} \mathrm{SO}_{4}\right)$ and catalyst silver sulphate $\left(\mathrm{Ag}_{2} \mathrm{SO}_{4}\right)$ to produce $\mathrm{CO}_{2}$ and $\mathrm{H}_{2} \mathrm{O}$. The excess of potassium dichromate remaining after the reaction is treated with ferrous ammonium sulphate. The dichromate consumed gives $\mathrm{O}_{2}$ required for oxidation of organic matter.

## Apparatus:

COD digestion vessel, COD digester, burette, pipette and beaker.

## Observations and calculations:

$$
\operatorname{COD}(\mathrm{mg} / L)=\frac{\{(B-A) * M * 8000\} * \text { dilution factor (if any) }}{\text { Volume of sample }}
$$

where:

$$
\begin{aligned}
& A=\text { FAS used for sample, } \mathrm{mL} \\
& B=\text { FAS used for blank, mL } \\
& M=\text { Normality of FAS }
\end{aligned}
$$

| Sl.no. | Sample |  | Burette reading |  | Dilution factor |
| :---: | :--- | :--- | :--- | :--- | :---: |
|  | Volume of FAS <br> consumed (ml) |  |  |  |  |
|  |  | Initial | Final |  |  |
| 1 | Hot blank |  |  |  |  |
|  | Diluted sample |  |  |  |  |
| 2 | Hot blank |  |  |  |  |
|  | Diluted sample |  |  |  |  |

## Reagents

Standard potassium dichromate solution 0.01667 M :
Add to about 500 mL distilled water 4.903 g K 2 Cr 2 O 7 , primary standard grade, previously dried at $150^{\circ} \mathrm{C}$ for $2 \mathrm{~h}, 167 \mathrm{~mL}$ conc. H2SO4, and 33.3 g HgSO 4 . Dissolve, cool to room temperature, and dilute to 1000 mL .

Sulphuric acid reagent: Add $5.5 \mathrm{~g} \mathrm{Ag}_{2} \mathrm{SO}_{4}$ technical or reagent grade, per kg of conc. $\mathrm{H}_{2} \mathrm{SO}_{4}$, keep for a day or two to dissolve.

Ferroin indicator solution: Dissolve 1.485g 1, 10-phenanthroline monohydrate and $695 \mathrm{mg} \mathrm{FeSO} 4.7 \mathrm{H}_{2} \mathrm{O}$ in distilled water and dilute to 100 mL . Commercially prepared may also be available.

Standard ferrous ammonium sulphate (FAS): 0.25M: Dissolve 98g
$\mathrm{Fe}\left(\mathrm{NH}_{4}\right)_{2}\left(\mathrm{SO}_{4}\right)_{2} .6 \mathrm{H}_{2} \mathrm{O}$ in distilled water, add 20 mL conc. $\mathrm{H}_{2} \mathrm{SO}_{4}$, cool and dilute to 1 L .

## Procedure

1. Take 2.5 ml of the sample in digestion vessel and add 1.5 ml of $\mathrm{K}_{2} \mathrm{Cr}_{2} \mathrm{O}_{7}$ solution and 3.5 ml of $\mathrm{Ag}_{2} \mathrm{SO}_{4}+\mathrm{H}_{2} \mathrm{SO}_{4}$ solution.
2. Place tubes in block digester preheated to $150^{\circ} \mathrm{C}$ and reflux for 2 h behind a protective shield.
3. Titrate mixture against ferrous ammonium sulphate (FAS) solution using ferroin indicator till blue green color turns to reddish brown color. Note down the volume of FAS used as ' A ' mL .
4. Repeat the experiment for blank sample (distilled water) and note down the volume of FAS used as 'B'mL.

## Results

The COD of the given water sample $=$

## Inference

Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks:

Dated signature of Faculty:

Date: $\qquad$

## 9. DETERMINATION OF VARIOUS TYPES OF SOLIDS

Solids refers to the residue remaining after a water/waste water sample has been evaporated and dried at a specified temperature $\left(103-105^{\circ} \mathrm{C}\right)$. High concentration of total solids will make drinking water unpalatable and might have an adverse effect on human beings. The main source of solids in water includes industrial discharge, sewage treatment plant, fertilizers, road runoff, soil erosion etc.

Total solids (TS) consist of total suspended solids and dissolved solids. Total dissolved solids (TDS) are mainly due to the organic matter present in solution in water. The main constituents are calcium, magnesium, sodium and potassium. Hardness, scaly deposits, sediments are some the effects caused by TDS. Total suspended solids (TSS) are the materials that are retained in the filter paper when the TDS is filtered.

The term fixed solids (FS) are applied to the residue remaining after evaporation, drying at $103^{\circ} \mathrm{c}$ followed by ignition at $600^{\circ} \mathrm{c}$. The loss of weight in oxidation and volatilization on ignition is called volatile solids (VS). Determination of fixed and volatile solids does not distinguish precisely between inorganic and organic matter because loss on ignition is not confined to organic matter. It includes losses on volatilization of some mineral salts. The ratio of the VS to FS is often used to characterize the waste water with respect to amount of organic matter present.

The term settleable solid refers to the materials in suspension settled due to gravitational force under quiescent condition. Settleable solids in surface and saline waters as well as domestic and industrial wastes may be determined and expressed in $\mathrm{ml} / \mathrm{l}$. It can be either determined by volumetric and gravimetric method. It is usually conducted in Imhoff cone which is graduated glass cone of 1L capacity with a narrow apex.


## Environmental significance:

Total solids measurements can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activities, sewage treatment plant discharges, and other sources. Total solids also affect water clarity. Higher solids decrease the passage of light through water, thereby slowing more rapidly and hold more heat; this, in turn, might adversely affect photosynthesis by aquatic plants.

Although the waste water or sewage normally contains 99.9 percent of water and only 0.1 percent of solids, but it is the solids that have the nuisance value. The amount of solids in wastewater is frequently used to describe the strength of the water. The more solids present in a particular wastewater, the stronger that wastewater will be. The environmental impacts of solids in all forms have detrimental effects on quality since they cause putrefaction problems.

Dissolved minerals, gases and organic constituents may produce aesthetically displeasing color, taste and odor. Some dissolved organic chemicals may deplete the dissolved oxygen in the receiving waters and some may be inert to biological oxidation, yet others have been identified as carcinogens. In industries, the use of water with high amount of dissolved solids may lead to scaling in boilers, corrosion and degraded quality of the product.

## Aim:

To find the total, suspended, dissolved, volatile, fixed, settleable solids present in the given sample.

## Principle:

The measurement of solids is by means of the gravimetric procedure. The various forms of solids are determined by weighing after the appropriate handling procedures. The total solids concentration of a sample can be found directly by weighing the sample before and after drying at $103^{\circ} \mathrm{C}$. However, the remaining forms, TDS and TSS require filtration of the sample. For liquid samples, all these solids levels are reported in $\mathrm{mg} / \mathrm{L}$.

## Apparatus:

Evaporating dishes/porcelain dish or crucible, drying oven, desiccator, weighing balance, Wattman filter paper, muffle furnace, filtration apparatus, Imhoff cone.

## Observations and calculations:

Total solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000$
where
$\mathrm{A}=$ weight of dish + residue, mg after evaporation and drying of sample at $103^{\circ} \mathrm{C}$
$B=$ weight of dish, mg
$\mathrm{V}=$ volume of sample $(\mathrm{mL})$

Total dissolved solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000$
where
A= Final weight of the dish, mg
$\mathrm{B}=$ weight of dish, mg
$\mathrm{V}=$ volume of sample ( mL )

Total suspended solids, $\mathrm{mg} / \mathrm{L}=\frac{(C-D)}{V} * 1000$
where
$\mathrm{C}=$ final weight of the filter paper containing the residue (mg)
$\mathrm{D}=$ initial weight of the filter paper ( mg )
$\mathrm{V}=$ volume of sample (mL)

Total volatile solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000$
where
$\mathrm{A}=$ weight of dish + residue, mg after evaporation and drying of sample at $103^{\circ} \mathrm{C}$
$B=$ Final weight of the dish, mg after evaporation of sample at $600^{\circ} \mathrm{C}$
$\mathrm{V}=$ volume of sample (mL)

Total fixed solids, $\mathrm{mg} / \mathrm{L}=$ Total solids - Total volatile solids

## Procedure:

## (i) Total solids:

1. Dry evaporating dish at $104 \pm 1^{\circ} \mathrm{C}$ for 1 hour, cool and store in a desiccator.
2. Weigh the dish immediately before use. Note down the weight as B.
3. Stir sample with a magnetic stirrer. While stirring, pipette a measured volume into the pre-weighed evaporating dish using a wide bore pipette.
4. Evaporate the sample to dryness in an oven at $104 \pm 1^{\circ} \mathrm{C}$. If necessary, add successive portions to the same dish after evaporation.
5. To prevent splattering, the oven temperature may be lowered initially by $2^{\circ} \mathrm{C}$ below boiling point and raised to $104^{\circ} \mathrm{C}$ after evaporation for 1 h . Cool in a desiccator and note down the weight as A .

## (ii) Total dissolved solids:

1. Measure the empty weight of porcelain dish and note down the reading as B.
2. Take known quantity of sample and pass it through the filter paper and collect the filtrate.
3. Dry the filtrate sample in oven at $103^{\circ} \mathrm{C}$ and cooled in a dessicator and note down the final weight as A.

## (iii) Total suspended solids:

1. Measure the empty weight of filter paper and note down reading as D .
2. Dry the filter paper with filtered sample in oven at $103^{\circ} \mathrm{C}$. Then cool it in a dessicator and note down the final weight as C .

## (iv) Total Volatile and fixed solids:

1. Keep the sample which is oven dried (sample used total solids, whose weight=A) in muffle furnace at a temperature of $600^{\circ} \mathrm{C}$ for 1 hour.
2. Cool the sample and note down the final weight as $B$. This will give the amount of volatile solids.
3. The difference between total solids and total volatile solids gives total fixed solids.

Total solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000=$
$=$
Total dissolved solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000=$
$=$
Total suspended solids, $\mathrm{mg} / \mathrm{L}=\frac{(C-D)}{V} * 1000=$
$=$
Total volatile solids, $\mathrm{mg} / \mathrm{L}=\frac{(A-B)}{V} * 1000=$

$$
=
$$

Total fixed solids, $\mathrm{mg} / \mathrm{L}=$ Total solids - Total volatile solids
$=$

|  | Concentration (mg/L) |
| :---: | :--- |
| TS |  |
| TDS |  |
| TSS |  |
| TVS |  |
| TFS |  |

## (v) Settleable solids:

1. Fill the imhoff cone with sample and mix thoroughly.
2. Allow the solids to settle for 1 hour and note down the volume of solids settled at the apex (in mL/L).

## Results

1). Total solids (TS) present in the given sample $=$ $\qquad$
2). Total dissolved solids (TDS) present in the given sample $=$ $\qquad$
3). Total suspended solids (TSS) present in the given sample $=$ $\qquad$
4). Total fixed solids (TFS) present in the given sample $=$ $\qquad$
5). Total volatile solids (TVS) present in the given sample $=$ $\qquad$
6). Total settable solids (SS) present in the given sample $=$. $\qquad$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

## 10. DETERMINATION OF THE MPN CONTENT

MPN is a procedure to estimate the population density of viable microorganisms in a test sample. It's based upon the application of the theory of probability to the numbers of observed positive growth responses to a standard dilution series of sample inoculums placed into a set number of culture media tubes. Positive growth response after incubation may be indicated by such observations as gas production in fermentation tubes or visible turbidity in broth tubes, depending upon the type of media employed.

## Environmental significance

A variety of different microorganisms are found in untreated water. Certain organisms, referred to as pathogens, cause disease to humans which include species of bacteria, viruses and protozoa. Although it is possible to detect the presence of various pathogens in water, the isolation and identification of many of these is often extremely complicated, time-consuming and expensive proposition. Hence in most cases (except when presence of any particular microorganism is suspected) the microbiological quality of water is checked using some indicator organisms.

An indicator organism is one whose presence presumes that contamination has occurred and suggests the nature and extent of the contaminants. An indicator organism should be a microorganism whose presence is evidence of fecal contamination of warm blooded animals. Indicators may be accompanied by pathogens, but typically do not cause disease themselves. Most common indicator used in microbial examination of water is coliforms which satisfy most of the conditions required for indicator organism. The measurement of total coliforms is of particular relevance for treated and / or chlorinated water supplies; in this case the absence of total coliforms would normally indicate that the water has been sufficiently treated / disinfected to destroy various pathogens. Measurement of focal coliforms is a better indicator of general contamination by material of fecal origin.

## Aim:

To determine to MPN content of the given water sample.

Table 12.1 MPN values per 100 ml of sample and $95 \%$ confidence limits for various combinations of positive and negative results (when three $10-\mathrm{ml}$, three 1ml , and three $0.1-\mathrm{ml}$ test portions are used)

| No. of tubes giving a positive reaction |  |  | $\begin{aligned} & \text { MPN (per } \\ & 100 \mathrm{ml} \text { ) } \end{aligned}$ | 95\% confidence limits |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3 of 10 ml | 3 of 1 ml | 3 of 0.1 ml |  | Lower | Upper |
| 0 | 0 | 1 | 3 | <1 | 9 |
| 0 | 1 | 0 | 3 | <1 | 13 |
| 0 | 0 | 0 | 4 | <1 | 20 |
| 1 | 0 | 1 | 7 | 1 | 21 |
| 1 | 1 | 0 | 7 | 1 | 23 |
| 1 | 1 | 1 | 11 | 3 | 36 |
| 1 | 2 | 0 | 11 | 3 | 36 |
| 2 | 0 | 0 | 9 | 1 | 36 |
| 2 | 0 | 1 | 14 | 3 | 37 |
| 2 | 1 | 0 | 15 | 3 | 44 |
| 2 | 1 | 1 | 20 | 7 | 49 |
| 2 | 2 | 0 | 21 | 4 | 47 |
| 2 | 2 | 1 | 28 | 10 | 149 |
| 3 | 0 | 0 | 23 | 4 | 120 |
| 3 | 0 | 1 | 39 | 7 | 130 |
| 3 | 0 | 2 | 64 | 15 | 379 |
| 3 | 1 | 0 | 48 | 7 | 210 |
| 3 | 1 | 1 | 75 | 14 | 230 |
| 3 | 1 | 2 | 120 | 30 | 380 |
| 3 | 2 | 0 | 93 | 15 | 380 |
| 3 | 2 | 1 | 150 | 30 | 440 |
| 3 | 2 | 2 | 210 | 35 | 470 |
| 3 | 3 | 0 | 240 | 36 | 1300 |
| 3 | 3 | 1 | 460 | 71 | 2400 |
| 3 | 3 | 2 | 1100 | 150 | 4800 |

## Principle:

Water to be tested is diluted serially and inoculated in lactose broth. Coliforms if present in water, utilize the lactose present in the medium to produce acid and gas. The presence of acid is indicated by color change of the medium and the presence of gas is detected as gas bubbles collected in the inverted durham tube present in the medium. The number of total coliforms is determined by counting the number of tubes giving positive reaction (i.e both colour change and gas production) and comparing the pattern of positive results (the number of tubes showing growth at each dilution) with standard statistical tables.

## Apparatus:

Test tubes of various capacities ( $20 \mathrm{ml}, 10 \mathrm{ml}, 5 \mathrm{ml}$ ), Durham tube, pipette, incubator, measuring cylinder, beaker, dropper etc.

## Reagents:

Appropriate culture medium (Lactose broth or Lauryl Tryptose broth)

## Procedure:

## 1. Presumptive test

1. Inoculate a series of fermentation tubes with appropriate quantity of culture medium. Mix 5.36 g of Lauryl Tryptose in 50 ml of distilled water to prepare double strength medium and 3.57 g in 150 ml to prepare single strength solution.
2. Take 12 test tubes and sterilize all the glasswares to be used. Add 10 ml of double strength solution in 3 test tubes and 10 ml single strength solution in other tubes.
3. Then add $10 \mathrm{ml}, 1 \mathrm{ml}$ and 0.1 ml of sample to the set 3 test tubes each. The remaining 3 test tubes are taken as the control and add 1 ml of distilled water.
4. Put Durham tubes in inverted position and remove the air bubble in it if any by slightly tilting the test tube after capping it with sterilized cotton.
5. Incubate all the tubes at $37^{\circ} \mathrm{C}$ for 24 hrs and examine for the presence of gas. If no tubes appear positive re-incubate up to 48 hrs .
6. Record the presence or absence of gas formation.
7. Gas formation in the inverted Durham tubes represents a positive presumptive test and a negative result indicates that the water is fit for drinking purpose.

## 2. Confirmed test

1. Brilliant green lactose broth (BGLB) is used for the confirmed test. BGLB media is prepared by dissolving 8 g of BGLB in 200 ml of distilled water.
2. Add 10 ml of BGLB medium in each 12 test tubes.
3. Add 1 ml of distilled water in first 3 tubes which is taken as control. Then transfer the medium in the positive tubes of the presumptive test to the BGLB tubes.
4. Incubate the inoculated tubes for $48 \pm 3 \mathrm{hrs}$ at $37^{\circ} \mathrm{C}$.
5. The formation of gas in the Durham tube indicate a positive confirmed test. If no gas is formed, it is a negative test and coliforms are absent.

## 3. Completed test

1. Streak one or more Eosine Methylene Blue (EMB) agar plates to get colonies. While streaking it is essential to ensure that the presence of some discrete colonies separated by at least 0.5 cm from one another.
2. Insert the end of the streaking needles into the liquid to a depth of 5 mm .
3. Streak the plate by bringing only the curved section of the needle in contact with agar surface, so that the latter will not be scratched.
4. Incubate the petridishes (inverted) at $37^{\circ} \mathrm{C}$ for $24 \pm 2 \mathrm{hrs}$.
5. The colonies developing on EMB agar may be typical or negative.
6. From each of these plates, streak out one or two colonies and transfer to Lauryl Tryptose broth fermentation tubes and to nutrient agar slants.
7. Incubate the secondary broth tubes and agar slants at $37^{\circ} \mathrm{C}$ for $24 \pm 2 \mathrm{hrs}$ or 48 $\pm 3 \mathrm{hrs}$ and if gas is not produced in 24 hrs , gram stained preparation from these agar slant culture is made.
8. The gas formation in the secondary broth tubes and demonstration of gram negative non-spore forming rod shaped bacteria in the agar culture may be considered as satisfactory positive completed test.
9. If after $48 \pm 3$ hrs gas is produced in the secondary fermentation tubes and no spores of gram positive rods are found on the slant, the test can besignaidner Not Verified

## Observations and calculations:

No. of tubes giving positive results:

| 3 of distilled <br> water | 3 of 10 ml each | 3 of 1 ml each | 3 of 0.1 ml each | MPN/100 ml |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |

as a positive completed test and this demonstrates the presence of coliform organisms.

## Computation of MPN

The number the positive results from fermentation should be computed as the combination of positive and recorded in terms of most probable number (MPN). The values at the $95 \%$ confidence limits for each of the MPN is determined. These values are prepared from 10,1 and 0.1 ml combination. If this combination is not available MPN may be estimated by following formula:

$$
\text { MPN } / 100 \mathrm{ml}=\frac{\text { No.of positive test tubes } * 10}{m l} \text { of sample in negative tubes } * \text { ml of sample in all tubes }
$$

## Result:

The value of MPN/ 100 ml is $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:
$\qquad$

## 11 DETERMINATION OF HARDNESS IN WATER

Hardness is caused by divalent metallic cations. The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. The major anions associated with these cations are sulphates, carbonates, bicarbonates, chlorides and nitrates. The hardness of water varies considerably from place to place. In general, surface water is softer than groundwater. The hardness of water reflects the nature of the geological formations with which it has been in contact.

The total hardness of water is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in $\mathrm{mg} / \mathrm{l}$. Hardness are of two types, temporary or carbonate hardness and permanent or non-carbonate hardness. Temporary hardness is one in which bicarbonate and carbonate ion can be precipitated by prolonged boiling. Non-carbonate ions cannot be precipitated or removed by boiling, hence the term permanent hardness. IS value for drinking water is $300 \mathrm{mg} / \mathrm{l}$ as CaCO 3

## Environmental significance

Hard water is as satisfactory for human consumption as soft waters. Because of their action with soap, however, their use for cleansing purpose is quite unsatisfactory, unless soap costs are disregarded. Soap consumption by hard waters represents an economic loss to the water user. Sodium soaps react with multivalent metallic cations to form a precipitate, thereby losing their surfactant properties. In recent years these problems have been largely alleviated by the developments of soaps and detergents that do not react with hardness. Boiler scale, the result of the carbonate hardness precipitation, may cause considerable economic loss through fouling of water heater and hot water pipes. Change in pH in the water distribution systems may also result in deposits of precipitates. Bicarbonates begin to convert to the less soluble carbonates at pH values above 9.0. Magnesium hardness, particularly associated with the sulfate ion has a laxative effect on persons unaccustomed to it. Magnesium concentrations of less than $50 \mathrm{mg} / \mathrm{l}$ are desirable in potable waters, although many public water supplies exceed the amount. Calcium hardness presents no public health problem. In fact, hard water is apparently beneficial to the human cardiovascular system

Observations and calculations:

1. Determination of Total Hardness

| Sl No | Volume of hard water <br> taken <br> (ml) | Burette reading (ml) |  | Vol. of EDTA <br> consumed (V3) (ml) |
| :--- | :--- | :--- | :--- | :--- |
|  |  | Initial | Final |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

2. Determination of Permanent Hardness

| Sl No | Volume of hard water <br> taken <br> (ml) | Burette reading (ml) |  | Vol. of EDTA <br> consumed (V4) (ml) |
| :--- | :--- | :--- | :--- | :--- |
|  |  | Initial | Final |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

## Aim:

To Determine Hardness of Given Water Sample

## Principle:

EDTA (Ethylenediamine tetra acetic acid) forms colorless stable complexes with Ca2+ and $\mathrm{Mg} 2+$ ions present in water at $\mathrm{pH}=9-10$. To maintain the pH of the solution at $9-10$, buffer solution ( $\mathrm{NH} 4 \mathrm{Cl}+\mathrm{NH} 4 \mathrm{OH}$ ) is used. Eriochrome Black-T (E.B.T) is used as an indicator. The sample of hard water must be treated with buffer solution and EBT indicator which forms unstable, wine-red colored complex s with $\mathrm{Ca} 2+$ and $\mathrm{Mg} 2+$ present in water

## Apparatus:

50 ml Burette, 20 ml Pipette, 250 ml Conical flask, 100 ml Beaker, 250 ml beaker, Glass funnel.

## Reagents:

EDTA solution, Standard CaCO3 solution, Eriochrome Black-T indicator, Buffer solution.

## Procedure:

## 1. Determination of Total hardness

(i) Pipette out 20 ml of sample hard water into a conical flask.
(ii) Add 5 ml of buffer solution and few drops of Eriochrome Black-T. The indicator, which is originally blue color would acquire a wine-red color.
(iii) Titrate with EDTA solution taken in the burette, till the wine red color changes to blue which is the end point. Let the burette reading of EDTA be $V_{3} \mathrm{ml}$.

## 3. Determination of Permanent hardness

Take 100 ml of sample hard water in 250 ml beaker. Boil it to remove temporary hardness to about half of this volume and cool to room temperature. Filter through filter paper to remove insoluble $\mathrm{CaCO}_{3}$ and $\mathrm{MgCO}_{3}$. Make up the volume to the original 100 ml by adding distilled water. Now pipette out 20 ml of this solution into a clean conical flask. Then repeat the process of titration steps as mentioned above. Let the burette reading of EDTA be $\mathrm{V}_{4} \mathrm{ml}$.

## CALCULATIONS:

## 1. Determination of Total hardness

$\mathrm{M}_{2} \mathrm{~V}_{2}=\mathrm{M}_{3} \mathrm{~V}_{3} \quad$ Where, $\mathrm{M}_{3}=$ Total hardness of sample water
$\mathrm{V}_{1}=$ Volume of sample hard water in conical flask

## 2 . Determination of Permanent hardness

$\mathrm{M}_{2} \mathrm{~V}_{2}=\mathrm{M}_{3} \mathrm{~V}_{3} \quad$ Where, $\mathrm{M}_{4}=$ Permanent hardness of sample water
$\mathrm{V}_{4}=$ Volume of sample hard water in conical flask
Note: Multiply M3 and M4 with 105 to covert hardness into parts per million (ppm).
3. Determination of Temporary hardness

Temporary hardness $=$ Total hardness - Permanent hardness

## RESULT:

Total Hardness present is a water sample is $\qquad$ .

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

Date: $\qquad$

## 12. DETERMINATION OF NITRATES AND PHOSPHATES

Nitrate and Phosphate are well-known contaminant of ground and stream water. It is an important environmental and human health analyte, and thus its detection and quantification are considered to be essential. Excess use of nitrate and phosphate rich fertilizers is dangerous, as it is neither taken up by plant nor retained by soil. Hence, it will be washed through into the drainage water and get into the rivers, polluting the water sources.

## Environmental Significance:

High concentration of phosphates and nitrates promote excessive growth of algae causing eutrophication. As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish.

Nitrites also react directly with hemoglobin in the blood of people to produce met hemoglobin which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease

## Aim:

To determine the nitrate and phosphate content in the given water sample.

## Principle:

Light absorption principle is used to determine the concentration of nitrate and phosphate in water sample.

## Apparatus:

UV-Visible Spectrophotometer, test tubes, pipette, water bath.

## Reagent:

1 bottle of reagent $\mathrm{NO}^{3}-1,1$ bottle of reagent $\mathrm{NO}^{3}-2$

## Observations and calculations:

| SI No. | Nitrate concentration <br> $(\mathrm{mg} / \mathrm{L})$ |
| :---: | :---: |
|  |  |
|  |  |
|  |  |
|  |  |


| Sl No. | Phosphate concentration <br> $(\mathrm{mg} / \mathrm{L})$ |
| :---: | :---: |
|  |  |
|  |  |
|  |  |
|  |  |

## Procedure:

## a) Nitrates

1. Calibrate the spectrophotometer using the autoselector.
2. Pipette out 4.0 ml of reagent $\mathrm{NO}_{3}-1$ into a dry test tube.
3. Add 0.50 ml of sample into the test tube and then add 0.50 ml of reagent $\mathrm{NO}_{3}-2$.
4. Leave the hot reaction sample to stand for 10 minutes
5. Fill the sample in the rectangular cell and measure in the photometer.

## b) Phosphates

1. Filter the given sample if it is turbid.
2. Check the pH of the sample. If the pH is not between $0-10$, adjust using sulphuric acid.
3. Pipette out 5.0 ml of the sample into the reaction cell and mix the sample after tightly closing the cell.
4. Measure the sample in the photometer.

## Result:

Concentration of nitrate in the given sample $=$
Concentration of phosphate in the given sample $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

Date: $\qquad$

## 13. DETERMINATION OF IRON CONTENT

Iron, as well as manganese, creates serious problems in public water supplies. The problems are most critical for groundwater. Iron exists in soils and minerals as insoluble ferric oxide/hydroxide and iron sulphide (pyrite). In some areas, it also occurs as ferrous carbonate, which is very slightly soluble. Since groundwater usually contains significant amounts of carbon dioxide, appreciable amounts of ferrous carbonate may be dissolved according to the following equation:

$$
\mathrm{FeCO}_{3}+\mathrm{CO}_{2}+\mathrm{H}_{2} \mathrm{O}=\mathrm{Fe}^{2+}+2 \mathrm{HCO}^{3-}
$$

If reducing (anaerobic) conditions exist in groundwater environment, the insoluble ferric iron $\left[\mathrm{Fe}^{3+}\right]$ is reduced to more soluble ferrous iron $[\mathrm{Fe} 2+]$ and iron concentration in water increases. There seems to be enough evidence to suggest that development of reducing (anaerobic) condition is essential for appreciable amount of iron (as well as manganese) to gain entrance into water.

## Environmental significance:

As far as is known, human suffer no harmful effects from drinking waters containing iron and manganese. Such waters, when exposed to the air so that oxygen can enter, become turbid and highly unacceptable from the aesthetic' viewpoint owing to the oxidation of iron and manganese to the $\mathrm{Fe}^{3+}$, and $\mathrm{Mn}^{4+}$ states which form colloidal precipitates. The rates of oxidation are not rapid, and thus reduced forms can persist for some time in aerated waters. This is especially true when the pH is below 6 with iron oxidation and below 9 with manganese oxidation. The rates may be increased by the presence of certain inorganic catalysts through the action of microorganisms.

Both iron and manganese interfere with laundering operations, impart objectionable stains to plumbing fixtures and cause difficulties in distribution systems by supporting growths of iron bacteria. Iron also imparts a taste to water, which is detectable at very low concentrations.

## Aim:

To determine the iron content in the given sample of water.

## Principle:

Iron may be present in two forms, namely the reduced form (ferrous, $\mathrm{Fe}^{2+}$ ) and the fully oxidized form (ferric, $\mathrm{Fe}^{3+}$ ). Ferric iron is seldom found in true solution in natural waters, unless they are highly acidic, because of the formation of insoluble ferric hydroxides. Ferrous iron is more likely to be found in true solution, although it is easily oxidized to the ferric state and precipitated in alkaline waters as ferric hydroxide.

Since some iron may exist as iron hydroxide precipitates, therefore it is necessary to bring precipitated form(s) of iron back into solution before oxidizing total iron content in water. For this hydrochloric acid is added to the test sample to dissolve the insoluble ferric forms. For determination of total iron by the following procedure, it must be ensured that all iron exists in ferric form $\left(\mathrm{Fe}^{3+}\right)$. This is most readily accomplished by using potassium permanganate, an oxidizing agent.

$$
5 \mathrm{Fe}^{2+}+\mathrm{MnO}_{4}^{-}+8 \mathrm{H}^{+}=5 \mathrm{Fe}^{3+}+\mathrm{Mn}^{2+}+4 \mathrm{H}_{2} \mathrm{O}
$$

Ferric iron is determined by producing a red-colored iron compound, ferric thiocyanate, by the addition of potassium thiocyanate (Eq.-9.3).

$$
\mathrm{Fe}^{3+}+3 \mathrm{KCNS}=\mathrm{Fe}(\mathrm{CNS})_{3}+3 \mathrm{~K}^{+}(\mathrm{red})
$$

The quantity of ferric iron is determined by comparison with the red color produced by standard iron solutions.

## Method I

## Apparatus:

Nessler tube, measuring cylinder, dropper

## Reagents:

Hydrochloric acid, potassium permanganate solution, Potassium thiocyanate solution and standard iron solution

## Procedure:

1. Place 100 mL of the water sample in a Nessler tube.
2. Add 5 mL of dilute hydrochloric acid

## Observations and calculations:

## Method I

Total iron conc. of the test sample ( $\mathrm{mg} / \mathrm{L}$ )
$=$ Standard iron solution added in distilled water $(\mathrm{mL}) *$ Conc. of standard iron solution(mg/L)
$m L$ of the sample taken

## Method II

| Sl No. | Total iron concentration <br> $(\mathrm{mg} / \mathrm{L})$ |
| :---: | :---: |
|  |  |
|  |  |
|  |  |
|  |  |

3. Add two drops of potassium permanganate solution.
4. Add 5 mL of potassium thiocyanate solution. The solution would turn brown if iron is present.
5. Compare the brown colour formed with the standard prepared as follows:
a. Add 100 mL of distilled water in a Nessler tube
b. Add 5 mL of the dilute hydrochloric acid.
c. Add two drops of potassium permanganate solution.
d. Add 5 mL of potassium thiocyanate solution.
e. Add 0.2 mL at a time of the standard iron solution until the color of the standard and the sample match.

## Method II

## Apparatus:

Spectrophotometer, test tubes

## Reagents:

1 bottle of reagent $\mathrm{Fe}-1,1$ bottle of reagent $\mathrm{Fe}-2,1$ bottle of reagent $\mathrm{Fe}-3$

## Procedure:

1. Calibrate the spectrophotometer using the autoselector.
2. Pipette out 8.0 ml of the sample into the test tube.
3. Add 1 drop of reagent $\mathrm{Fe}-1$ and mix.
4. Then add 0.5 ml of reagent $\mathrm{Fe}-2$ and mix.
5. Add 1 dose of reagent $\mathrm{Fe}-3$ and shake vigorously till the reagent is completely dissolved.
6. Leave the sample to stand for 10 minutes, then fill the sample into the cell, and measure the concentration in the photometer.

## Result:

The iron content of the given water sample $=$

## Inference

## Performance of student and Evaluation:

| Category | Excellent <br> Above 80\% | Good <br> $61 \%-80 \%$ | Satisfactory <br> Below 60\% |
| :--- | :---: | :---: | :---: |
| Punctuality \& Dress code <br> (5 Marks) |  |  |  |
| Knowledge of Theory <br> (5 Marks) |  |  |  |
| Conduction (5 Marks) |  |  |  |
| Calculation (5 Marks) |  |  |  |
| Result (5 Marks) |  |  |  |
| Viva (5 Marks) |  |  |  |

Marks: / 30

Dated signature of Faculty:

VIMAL JYOTHI
ENGINEERING COLLEGE

# VIMAL JYOTHI ENGINEERING COLLEGE, CHEMPERI, DEPARTMENT OF CSE CSL 201 DATA STRUCTURES LAB MANUAL 

## A. POLYNOMIAL ADDITION USING ARRAY

```
PROGRAM
#include <stdio.h>
#include <math.h>
struct poly
{
int coeff;
int exp;
};
struct poly p1[10],p2[10],p3[10];
int main()
{
int i,d=0;
int deg1,deg2;
printf("Enter highest degree of poly1:");
scanf("%d",&deg1);
for(i=0;i<=deg1;i++)
{
printf("\nEnter the coefficient of x^%d:",i);
scanf("%f",&p1[i].coeff);
p1[i].exp=i;
}
printf ("\nEnter the highest degree of poly2:");
scanf("%d",&deg2);
for(i=0;i<=deg2;i++)
{
printf("\nEnter the coefficient of x^%d:",i);
scanf("%f",&p2[i].coeff);
p2[i].exp=i;
}
printf ("\n Expression 1=%f",p1[0].coeff);
for(i=1;i<=deg1;i++)
```

\{

```
printf("+%fx^%d",p1[i].coeff,p1[i].exp);
}
for(i=1;i<=deg2;i++)
{
printf("+%fx^%d",p2[i].coeff,p2[i].exp);
}
if(deg1>deg2)
{
for(i=0;i<=deg2;i++)
{
p3[d].coeff=p1[i].coeff+p2[i].coeff;
p3[d].exp=p1[i].exp;
d++;
}
for(i=deg2+1;i<=deg1;i++)
{
p3[d].coeff=p1[i].coeff;
p3[d].exp=p1[i].exp;
d++;
}
}
else
{
for(i=0;i<=deg1;i++)
{
p3[d].coeff=p1[i].coeff+p2[i].coeff;
p3[d].exp=p1[i].exp;
d++;
}
for(i=deg1+1;i<=deg2;i++)
{
p3[d].coeff=p2[i].coeff;
p3[d].exp=p2[i].exp;
d++;
}
```

printf ("\n Expression after addition=\%f",p3[0].coeff);
for(i=1;i<d;i++)
\{
printf("+\%fx^\%d",p3[i].coeff,p3[i].exp);
\}
return 0;
\}

## OUTPUT



[^0]
## B. TRANSPOSE AND SUM OF TWO SPARSE MATRICES

## PROGRAM

\#include <stdio.h>
struct sparse\{
int row;
int col;
int value;
\}sp1[20],sp2[20],tr1[20],tr2[20];
//TUPLE FORM
void tuple(struct sparse $\mathrm{sp}[20]$,int a [20][20],int r1,int c1)
\{
$\mathrm{sp}[0]$.row $=\mathrm{r} 1$;
$\mathrm{sp}[0] . \mathrm{col}=\mathrm{c1}$;
int $k=1, i, j ;$
for(i=0;i<r1;i++)
\{
for ( $\mathbf{j}=\mathbf{0} ; \mathbf{j}<\mathbf{c} 1 ; \mathrm{j}++$ )
\{
if(a[i][j] ! $=0$ )
\{
$s p[k] \cdot$ row $=\mathrm{i}$;
sp[k].col = j;
$\mathbf{s p}[k]$.value $=a[i][j] ;$
k++;
\}
\}
\}
$\mathrm{sp}[0]$.value $=\mathrm{k}-1$;
printf("row\tcol\tvalue\n");
printf("\%d\t\%d $\backslash \mathrm{t} \% \mathrm{~d} \backslash \mathrm{n}$ ",sp[0].row,sp[0].col,sp[0].value);
for(i=1;i<k;i++)
\{
printf("\%d\t\%d\t\%d\n",sp[i].row,sp[i].col,sp[i].value);
\}
Signature Not Verified
\}

## //ADDITION IN TUPLE FORM

```
void add()
{
struct sparse r[20];
int i=1,j=1,k=1;
r[0].row = sp1[0].row;
r[0].col = sp1[0].col;
while(i<=sp1[0].value && j<=sp2[0].value)
{
if(sp1[i].row == sp2[j].row && sp1[i].col ==
sp2[j].col)
{
r[k].row = sp1[i].row;
r[k].col = sp1[i].col;
r[k].value = sp1[i].value + sp2[j].value;
i++;
j++;
k++;
}
else if(sp1[i].row <= sp2[j].row)
{
r[k].row = sp1[i].row;
r[k].col = sp1[i].col;
r[k].value = sp1[i].value;
i++;
k++;
}
else if(sp1[i].row >= sp2[j].row)
{
r[k].row = sp2[j].row;
r[k].col = sp2[j].col;
r[k].value = sp2[j].value;
j++;
k++;
}
```

while(i <= sp1[0].value )
\{
r[k].row = sp1[i].row;
r[k].col = sp1[i].col;
$r[k]$.value $=s p 1[i]$.value;
i++;
k++;
\}
while( j <= sp2[0].value)
\{
r[k].row = sp2[j].row;
r[k].col = sp2[j].col;
$r[k]$.value $=s p 2[j]$.value;
j++;
k++;
\}
$r[0]$.value $=k-1$;
printf("row\tcol\tvalue\n");
printf("\%d\t\%d\t\%d\n",r[0].row,r[0].col,r[0].value);
for(i=1; $\mathbf{i}<\mathbf{k} ; \mathbf{i + +}$ )
\{
printf("\%d\t\%d\t\%d\n",r[i].row,r[i].col,r[i].value);
\}
\}
//TRANSPOSE INTUPLE FORM
void transpose(struct sparse spt1[20],struct sparse spt2[20])
\{
spt2[0].row = spt1[0].row;
spt2[0].col = spt1[0].col;
spt2[0].value = spt1[0].value;
int $k=1, i, j ;$
for(i=0;i<=spt1[0].col;i++)
\{
for(j=0;j<=spt1[0].value;j++)
if(spt1[j].col == i)
\{
spt2[k].row = spt1[j].col;
spt2[k].col = spt1[j].row;
spt2[k].value $=s p t 1[j] . v a l u e ;$
k++;
\}
\}
\}
printf("row\tcol\tvalue\n");
for(i=0;i<k-1;i++)
\{
printf("\%d $\backslash \% d \backslash t \% d \backslash n "$, spt2[i].row,spt2[i].col,spt2[i].value);
\}
\}
void main()\{
int r1,r2,c1,c2,a[20][20],b[20][20],i,j;
printf("Enter the row of matrix A : ");
scanf("\%d",\&r1);
printf("Enter the column of matrix A : ");
scanf("\%d",\&c1);
for(i=0;i<r1;i++)
\{
for(j=0;j<c1;j++)
\{
printf("Enter the elements to array A[\%d][\%d] :
",i,j);
scanf("\%d",\&a[i][j]);
\}
\}
printf("Matix A\n");
for(i=0;i<r1;i++)
\{
for $(\mathrm{j}=0 ; \mathrm{j}<\mathrm{c} 1 ; \mathrm{j}++$ )

```
{
printf("%d\t",a[i][j]);
}
printf("\n");
}
printf("Enter the row of matrix B : ");
scanf("%d",&r2);
printf("Enter the column of matrix B : ");
scanf("%d",&c2);
for(i=0;i<r2;i++)
{
for(j=0;j<c2;j++)
{
printf("Enter the elements to array A[%d][%d] :
",i,j);
scanf("%d",&b[i][j]);
}
}
printf("Matix B\n");
for(i=0;i<r2;i++)
{
for(j=0;j<c2;j++)
{
printf("%d\t",b[i][j]);
}
printf("\n");
}
printf("Tuple form of Matrix A\n");
tuple(sp1,a,r1,c1);
printf("Tuple form of Matrix B\n");
tuple(sp2,b,r2,c2);
printf("Transpose of Matrix A\n");
transpose(sp1,tr1);
printf("Transpose of Matrix B\n");
transpose(sp2,tr2);
```

if(r1==r2 \&\& c1==c2)

## \{

printf("Addition of two Matrix A and B \n");
add(r1,c1);
\}
else
printf("Addition not possible\n");
\}
OUTPUT


## 2.IMPLEMENTATION OF STACK , QUEUES , PRIORITY QUEUES, DEQUEUE \& CIRCULAR QUEUES USING ARRAY

## A. STACK

## PROGRAM

\#include<stdio.h>
void main()
\{
int sk[50],top=-1,k,n,i,s;
char ch;
printf("\n\tEnter the size of the stack:") ;
scanf("\%d",\&s);
do
\{
printf("\n\t\tLIST");
printf("\n\n\t1.Push\n\n\t2.Pop\n\n\t3.Display\n\n\t4.Exit");
printf("\n\n\tEnter your choice:");
scanf("\%d",\&n);
if( $n==1$ )
\{
if(top==s-1)
\{
printf("\n\tStack is overflow");
\}
else
\{
printf("\n\tEnter the element to be inserted:");
scanf("\%d",\&k);
top++;
sk[top]=k;
printf("\n\tThe entered element is \%d",sk[top]);
\}
\}
else if( $n==2$ )

```
if(top==-1)
{
printf("\n\tStack is underflow");
}
else
{
printf("\n\tThe deleted element is %d",sk[top]);
top--;
}
}
else if(n==3)
{
if(top==-1)
{
printf("\n\tStack underflow");
}
else
{
printf("\n\tThe stack is:");
for(i=top;i>=0;i-)
{
printf("\t\t%d",sk[i]);
}
}
}
else
{
break;
}
printf("\n\n\tDo you want to continue (Y/N) ?");
scanf(" %c",&ch);
}
while((ch=='Y')||(ch=='y'));
```

\}

## OUTPUT



Do you want to continue ( $\mathrm{Y} / \mathrm{N}$ ) ? y
LIST
1.Push
2. Pop
3.Display
4. Exit

Enter your choice:2
The deleted element is 4
Do you want to continue ( $\mathrm{Y} / \mathrm{N}$ ) ? ?

1. Push
2. Pop
3.Display
3. Exit

Enter your choice:3
The stack is:
Do you want to continue ( $\mathrm{Y} / \mathrm{N}$ ) ?

## B. QUEUE

```
PROGRAM
#include<stdio.h>
void main()
{
int n,i,front=-1,rear=-1,a,q[50],k,s;
char ch;
printf("\n\n\tEnter the size of the queue: ");
scanf("%d",&s);
do
{
printf("\n\n\n\t\t\t\tLIST\n\n");
printf("\t\t1.INSERT\n\n\t\t2.DELETE\n\n\t\t3.DISPLAY\n\n\t\t4.EXIT");
printf("Enter your choice");
scanf("%d",&n);
if(n==1)
{
if(rear==(s-1))
printf("\n\t\tOverflow");
else
{
printf("\n\n\t\tEnter the element: ");
scanf("%d",&k);
if(front==-1&&rear==-1)
front=0;
rear++;
q[rear]=k;
}
}
if(n==2)
{
if(front==-1)
```

printf("\n\t\tUnderflow\n");
else
\{
$\mathrm{a}=\mathrm{q}$ [front];
printf("\n\t\tDeleted element is \%d ",a);
\}
if(front==rear)
front=rear=-1;
else
front++;
\}
if( $n==3$ )
\{
if(front==-1\&\&rear==-1)
printf("\n\t\tUnderflow\n");
else
\{
printf("\n\t\tQueue elements are\n ");
for(i=front;i<=rear;i++)
\{
printf("\n\n\t\t\%d",q[i]);
\}
\}
\}
if( $n==4$ )
break;
printf("\n\n\t\tDo you want to continue(y/n) ");
scanf(" \%c",\&ch);
\}
while(ch=='y'||ch=='Y');

Enter the size of the queue: 4

LIST

1. INSERT
2.DELETE
3.DISPLAY
4.EXITEnter your choice1

Enter the element: 2

Do you want to continue(y/n) Y

LIST

1. INSERT
2.DELETE
3.DISPLAY
4.EXITEnter your choice1

Enter the element: 3

Do you want to continue( $\mathrm{y} / \mathrm{n}$ ) Y

## LIST

1. INSERT
2. DELETE
3.DISPLAY
4.EXITEnter your choice3

Queue elements are

2

3

3

5

Do you want to continue $(y / n) Y$

LIST

1. INSERT
2.DELETE
2. DISPLAY
4.EXITEnter your choice2

Deleted element is 2

Do you want to continue $(y / n) Y$

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## C.PRIORITY QUEUE

## PROGRAM

\#include <stdio.h>
\#include <stdlib.h>
\#define M 20
void enqueue(int);
void dequeue(int);
void check(int);
void display();
int $p q[M]$;
int $f=-1, r=-1$;
void main()
\{
int n , ch ;
printf("\n1. Insert an element");
printf("\n2. Delete an element");
printf("\n3. Display the elements");
while (1)
\{
printf("\nEnter your choice : ");
scanf("\%d", \&ch);
switch (ch)
\{
case 1 :
printf("\nEnter value to be inserted : ");
scanf("\%d",\&n);
enqueue(n);
break;
case 2:
printf("\nEnter value to delete : ");
scanf("\%d",\&n);
dequeue(n);
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break;

```
            case 3:
                    display();
                    break;
            default:
                printf("\nPlease Enter a valid choice");
        }
    }
}
void enqueue(int data)
{
        if (r>= M-1)
    {
        printf("\nQUEUE IS OVERFLOW");
        return;
    }
    if ((f ==-1) && (r==-1))
    {
        f++;
        r++;
        pq[r] = data;
        return;
    }
    else
        check(data);
    r++;
}
void check(int data)
{
    int i,j;
    for (i=0; i<=r;i++)
    {
        if (data >= pq[i])
        {
        for(j=r+1;j>i;j--)
```

```
        {
                pq[j]=pq[j-1];
        }
        pq[i] = data;
        return;
        }
    }
    pq[i]=data;
}
void dequeue(int data)
{
    int i;
    if ((f==-1) && (r==-1))
    {
        printf("\nQUEUE IS EMPTY\n");
        return;
    }
    for (i=0;i<=r;i++)
    {
        if (data== pq[i])
    {
        for (;i<r;i++)
        {
            pq[i] = pq[i+1];
        }
    pq[i] = -99;
    r--;
    if (r ==-1)
        f=-1;
    return;
    }
```

    printf("\n\%d not found", data);
    \}
void display()
\{
if $((f==-1) \& \&(r==-1))$
\{
printf("\nQUEUE IS EMPTY");
return;
\}
printf("Elements in the queue is ");
for (; $\mathbf{f}<=\mathbf{r} ; \mathbf{f + +}$ )
\{
printf(" \%d ", pq[f]);
\}
$\mathrm{f}=\mathbf{0}$;
\}

## OUTPUT



## D.DEQUEUE

## PROGRAM

\#include<stdio.h>
\#include<conio.h>
void main()
\{
int no,i,front=-1,rear=-1,k,q[50],a,n;
char c ;
printf("\n\tEnter the size of the queue: ");
scanf("\%d",\&n);
do
\{
printf("\t\t\t\tMENU\n");
printf("\t\t1.INSERT_FRONT\n\t\t2.INSERT_END\n\t\t3.DELETE_FRONT\n\t\t4.DELETE_END\n\t\t5.DISPLAY\n\t\t6.EXI T ");
printf("\n\n\tEnter your choice:");
scanf("\%d",\&no);
if(no==1)
\{
if(front==0)
printf("\t\tOverflow\n");
else
\{
printf("\t\tEnter the element: ");
scanf("\%d",\&k);
if(front==-1)
\{front=0;
rear=0;
$q[$ front $]=k ;$
\}
else if(front! $=0$ )
\{
front=front-1;
$q[$ front $]=k ;$
\}
\}
if( $\mathrm{no}==2$ )
\{
if(rear==n-1)
printf("\t\tOverflow\n");
else
\{
printf("\t\tEnter the element: ");
scanf("\%d",\&k);
$i f($ front $=-=1$ )
\{
front=rear=0;
q[rear]=k;
\}
else
\{
rear=rear+1;
q[rear]=k;
\}
\}
\}
if(no==3)
\{
if(front==-1)
printf("\t\tUnderflow\n");
else
\{
$\mathrm{a}=\mathrm{q}[$ front];
printf("\t\tDeleted element is \%d ",a);
printf("\n");
if(front==rear)
front=rear=-1;
else
front++;
if( $\mathrm{no}==4$ )
\{
if(rear=- -1 )
printf("\t\tUnderflow\n");
else
\{
$\mathrm{k}=\mathrm{q}[\mathrm{rear}]$;
printf("\t\tDeleted element is \%d ",k);
printf("\n");
if(front==rear)
front=rear=-1;
else
rear--;
\}
\}
if( $\mathrm{no}==5$ )
\{
if(front=--1\&\&rear=- -1 )
printf("\t\tUnderflow\n");
else
\{
printf("\t\tQueue elements are ");
for(i=front;i<=rear;i++)
printf("\%d ",q[i]);
printf("\n");
\}
\}
if(no==6)
break;
printf("\t\tDo you want to continue(y/n) ");
scanf(" \%c",\&c);
\}
while( $c==' y$ ' | | $c==' Y^{\prime}$ ');

OUTPUT

Enter the size of the queue: 4
1.INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6.EXIT

Enter your choice:1
Enter the element: 2
Do you want to continue( $\mathrm{y} / \mathrm{n}$ ) Y MENU
1.INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6.EXIT

Enter your choice:2
Enter the element: 6
Do you want to continue( $\mathrm{y} / \mathrm{n}$ ) Y MENU
1.INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6.EXIT

Enter your choice: 5
Queue elements are 26
Do you want to continue $(\mathrm{y} / \mathrm{n}) \mathrm{Y}$ MENU
1.INSERT_FRONT
2. INSERT_END
3.DELETE_FRONT
4.DELETE END
5.DISPLAY
6.EXIT

Enter your choice:3
Deleted element is 2
Do you want to continue( $\mathrm{y} / \mathrm{n}$ ) y
1.INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE END
5. DISPLAY
6.EXIT

Enter your choice: 5
Queue elements are
Do you want to continue $(\mathrm{y} / \mathrm{n}) \mathrm{Y}$ MENU
1.INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6.EXIT

Enter your choice:1
Enter the elent:
Do you want to continue ( $\mathrm{y} / \mathrm{n}$ ) Y5 MENU

## 1.INSERT_FRONT

2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6. EXIT

Enter your choice:
Queue elements are 56
Do you want to continue $(\mathrm{y} / \mathrm{n}) \mathrm{Y}$

1. INSERT_FRONT
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
2. DISPLAY
6.EXIT

Enter your choice:4
Deleted element is 6
Do you want to continue $(\mathrm{y} / \mathrm{n})$ y
MENU
1.INSERT_FRON
2.INSERT_END
3.DELETE_FRONT
4.DELETE_END
5.DISPLAY
6.EXIT

## E.CIRCULAR QUEUE

PROGRAM
\#include <stdio.h>
int maxs;
int item[50];
int front $=\mathbf{- 1}$;
int rear = $\mathbf{- 1}$;
//ENQUEUE FUNCTION
void enqueue()
\{
int data;
printf("Enter the element : ");
scanf("\%d",\&data);
if(front==-1 \&\& rear ==-1)
\{
front=rear=0;
item[rear] = data;
\}
else if(((rear+1)\%maxs)==front)
\{
printf("Queue is full\n");
\}
else
\{
rear = (rear+1)\%maxs;
item[rear] = data;
\}
\}
//DEQUEUE FUNCTION
void dequeue()
\{
int data;
if(front==-1 \&\& rear==-1)
printf("queue is empty\n");
else if(front==rear)//if single element is present in the
queue
\{
printf("The deleted data is \%d ",item[front]);
front=-1;
rear=-1;
\}
else
\{
data $=$ item[front];
front $=($ front +1$) \%$ maxs;
printf("The deleted item is \%d ",data);
\}
\}
//DISPLAY FUNCTION
void display()
\{
int i ;
for(i=front;i!=rear;)
\{
printf("\%d\n",item[i]);
$\mathrm{i}=(\mathrm{i}+1) \%$ maxs;
\}
printf("\%d\n",item[rear]);
\}
void main()
\{
printf("Enter the size of queue :");
scanf("\%d",\&maxs);
int $\mathrm{ch}=1$;
while(ch==1)
\{
printf("1.Enqueue\n2.Dequeue\n3.Display\n");
int n ;
printf("Enter your choice : ");
scanf("\%d",\&n);
switch(n)
\{
case 1:
enqueue();
break;
case 2 :
dequeue();
break;
case 3:
display();
break;
default:
break;
\}
printf("Do u want to continue Y:1 or N:0");
scanf("\%d",\&ch);
if(ch==0)
break;
else
continue;
\}
\}
OUTPUT


## 3.APPLICATION PROBLEMS USING STACKS: CONVERSION FROM ONE NOTATION TO ANOTHER NOTATION <br> INFIX EXPRESSION TO POSTFIX EXPRESSION CONVERSION

## PROGRAM

\#include <stdio.h>
\#include <ctype.h>
\#define MAX 50
int top = -1;
char stack[MAX];
//PUSH FUNCTION
void push (char el)
\{
stack[++top] = el;
\}
//POP FUNCTION
char pop ()
\{
return (stack[top--]);
\}
//PRIORITY CHECKING
int priority (char sym)
\{
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if (sym == '^')
return (3);
else if (sym == '*' || sym == '/')
return (2);
else if (sym == '+' || sym == '-')
return (1);
else
return (0);
\}
void main ()
\{
char infix[50], postfix[50], c, el;
int $\mathrm{i}=0, \mathrm{j}=0$;
printf ("Enter infix expression : ");
scanf ("\%s", infix);
push ('\$');
while ((c = infix[i++]) != '\0')
\{
if ( $c==$ '(')
push (c);
else if (isalnum (c))
postfix[j++] = c;
else if ( $c==$ ')')
\{
while (stack[top] != '(')
postfix[j++] = pop ();
el $=\operatorname{pop}()$;
\}
else
\{
while (priority (stack[top]) >= priority (c))
postfix[j++] = pop ();
push (c);
\}
\}
while (stack[top] != '\$')
postfix[j++] = pop ();

```
postfix[j] = '\0';
printf ("\nPostfix Expression = %s\n", postfix);
}
```

OUTPUT

# Enter infix expression : (a*b)+(c-d)/f*g <br> Postfix Expression = ab*cd-f/g*+ <br> Process returned 34 ( $0 \times 22$ ) execution time : 28.937 s <br> Press any key to continue. 

## 4.IMPLEMENTATION OF VARIOUS LINKED LIST OPERATIONS

## PROGRAM

\#include <stdio.h>
\#include <stdlib.h>
struct node
\{
int data;
struct node *next;
\} *head, *new, *ptr, *prv, *current;
void
insertb ()
\{
int item;
printf ("Enter the element to insert :");
scanf ("\%d", \&item);
new = (struct node *) malloc (sizeof (struct node));
if(head==NULL)
\{
new->data = item;
new->next = head;
head = new;
head -> next = NULL;
\}

```
new->data = item;
new->next = head;
head = new;
}
}
void inserte ()
{
int item;
printf ("Enter the element : ");
scanf ("%d", &item);
ptr = head;
while (ptr->next != NULL)
{
ptr = ptr->next;
}
new = (struct node *) malloc (sizeof (struct node));
ptr->next = new;
new->data = item;
new->next = NULL;
}
void insertbt ()
{
int key;
printf ("Enter the key : ");
scanf ("%d", &key);
int item;
printf ("Enter the element to insert :");
scanf("%d",&item);
new = (struct node *) malloc (sizeof (struct node));
ptr = head;
while (ptr->data != key && ptr->next != NULL)
{
ptr = ptr->next;
}
if (ptr->next == NULL)
```

printf ("Key not found $\backslash n$ ");
\}
else
\{
new->data = item;
new->next = ptr->next;
ptr->next = new;
\}
\}
void deleteb ()
\{
ptr = head;
if ( $p$ tr $==$ NULL)
printf ("it is empty");
else
\{
int element $=$ head->data;
head = head->next;
printf ("The item deleted is \%d\n", element);
\}
\}
void deletee ()
\{
prv = current = head;
while (current->next != NULL)
\{
prv = current;
current $=$ current->next;
\}
int item = current->data;
prv->next = NULL;
printf ("The deleted element is \%d", item);
\}
void deletebt ()
int key;
scanf ("Enter the key : ");
scanf ("\%d", \&key);
current = prv = head;
while (current->data != key \&\& current->next != NULL)
\{
prv = current;
current $=$ current->next;
\}
int item = current->data;
printf ("The deleted element is \% $\mathrm{d} \backslash \mathrm{n}$ ", item);
if (current->next == NULL)
\{
printf ("Key not found $\backslash n$ ");
\}
else
\{
prv->next = current->next;
\}
\}
void display ()
\{
int item;
ptr = head;
printf ("data\n");
while (ptr->next != NULL)
\{
item = ptr->data;
printf ("\%d\n", item);
ptr $=$ ptr->next;
\}
item = ptr->data;
printf ("\%d\n", item);
\}

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void main ()
\{
int ch = 1;
while (ch == 1 )
\{
printf("1.Insert
beginning\n2.Insertend \n3.Insertbetween\n4.Deletebeginning\n5.Deleteend\n6.Deletebetween\n7.Display\n");
int $\mathbf{n}$;
printf ("Enter your choice :");
scanf ("\%d", \&n);
switch ( n )
\{
case 1:
insertb ();
break;
case 2:
inserte ();
break;
case 3:
insertbt ();
break;
case 4:
deleteb ();
break;
case 5:
deletee ();
break;
case 6:
deletebt ();
break;
case 7:
display ();
break;
default:
break;
\}
printf ("Do u want to continue : Y|1 N|0 : \n");
scanf("\%d",\&ch);
if (ch $==0$ )
break;
else
continue;
\}
\}

## OUTPUT



## 5.REPRESENTATION OF POLYNOMIALS USING LINKED LIST,ADDITION \& MULTIPLICATION OF POLYNOMIALS

## A.SUM OF TWO POLYNOMIAL USING LINKED LIST

```
PROGRAM
#include<stdio.h>
#include<stdlib.h>
struct poly
{
    int coeff;
    int expn;
    struct poly* next;
}*Phead=NULL,*Qhead=NULL,*Rhead,*pptr,*qptr,*rptr,*new;
void main()
{
    int i,n;
    printf("enter the no of terms of 1st poly :");
    scanf("%d",&n);
    for(i=0;i<n;i++)
    {
        int c,e;
        printf("Enter the coefficient:");
        scanf("%d",&c);
        printf("Enter the exponenet:");
        scanf("%d",&e);
        if(Phead==NULL)
    {
        new=(struct poly*)malloc(sizeof(struct poly));
        new->coeff=c;
        new->expn=e;
        new->next=NULL;
        Phead=new;
    }
Signature Not Verified
```

```
    else
    {
    new=(struct poly*)malloc(sizeof(struct poly));
    pptr=Phead;
    while(pptr->next!=NULL)
        pptr=pptr->next;
        new->coeff=c;
        new->expn=e;
        new->next=NULL;
        pptr->next=new;
    }
}
pptr=Phead;
printf("1st poly");
while(pptr!=NULL)
{
    if(pptr==Phead)
        printf("%dx^%d",pptr->coeff,pptr->expn);
    else
        printf("+%dx^%d",pptr->coeff,pptr->expn);
        pptr=pptr->next;
}
printf("\n");
int j,k;
printf("enter the no.of terms of 2nd poly:");
scanf("%d",&k);
for(j=0;j<k;j++)
{
        int c,e;
        printf("Enter the coefficient");
        scanf("%d",&c);
        printf("enter the exponent");
        scanf("%d",&e);
```

```
if(Qhead==NULL)
{
    new=(struct poly*)malloc(sizeof(struct poly));
    new->coeff=c;
    new->expn=e;
    new->next=NULL;
    Qhead=new;
}
else
{
    new=(struct poly*)malloc(sizeof(struct poly));
    qptr=Qhead;
    while(qptr->next!=NULL)
        qptr=qptr->next;
        new->coeff=c;
        new->expn=e;
        new->next=NULL;
        qptr->next=new;
    }
}
qptr=Qhead;
printf("2nd poly");
while(qptr!=NULL)
{
    if(qptr=Qhead)
        printf("%dx^%d",qptr->coeff,qptr->expn);
        else
        printf("+%dx^%d",qptr->coeff,qptr->expn);
    qptr=qptr->next;
}
printf("\n");
pptr=Phead;
qptr=Qhead;
Rhead=(struct poly*)malloc(sizeof(struct poly));
rptr=Rhead;
```

```
while(pptr!=NULL&&qptr!=NULL)
```

\{
if(pptr->expn==qptr->expn)
\{
new=(struct poly*)malloc(sizeof(struct poly));
rptr->next=new;
rptr->expn=pptr->expn;
rptr->coeff=pptr->coeff+qptr->expn;
rptr->next=NULL;
pptr=pptr->next;
qptr=qptr->next;
\}
else if(pptr->expn>qptr->expn)
\{
new=(struct poly*)malloc(sizeof(struct poly));
rptr->next=new;
rptr->expn=pptr->expn;
rptr->coeff=pptr->coeff;
rptr->next=NULL;
pptr=pptr->next;
\}
else
\{
new=(struct poly*)malloc(sizeof(struct poly));
rptr->next-new;
rptr->expn=qptr->expn;
rptr->coeff=qptr->coeff;
rptr->next=NULL;
qptr=qptr->next;
\}
\}
while(pptr!=NULL)
\{
new=(struct poly*)malloc(sizeof(struct poly));
rptr->next=new;

```
            rptr->expn=pptr->expn;
            rptr->coeff=pptr->coeff;
            rptr->next=NULL;
            pptr=pptr->next;
    }
    while(qptr!=NULL)
    {
    new=(struct poly*)malloc(sizeof(struct poly));
            rptr->next-new;
            rptr->expn=qptr->expn;
            rptr->coeff=qptr->coeff;
            rptr->next=NULL;
            qptr=qptr->next;
    }
    printf("Addition of 2 polynomials");
    rptr=Rhead->next;
    while(rptr!=NULL)
    {
        printf("%dx^%d",rptr->expn,rptr->coeff);
        if(rptr->next!=NULL)
        printf("+");
        rptr=rptr->next;
    }
    printf("\n");
}
```


## OUTPUT

```
Enter polynomial1:
```

Enter polynomial1:
Enter degree of polynomial:4
Enter degree of polynomial:4
Enter Coefficient of x:4
Enter Coefficient of x:4
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of x}x:
Enter Coefficient of x}x:
polynomial1: 4.00(\mp@subsup{x}{}{\wedge}4)+3.00(\mp@subsup{x}{}{\wedge}3)+6.00(\mp@subsup{x}{}{\wedge}2)+7.00(\mp@subsup{x}{}{\wedge}1)+8-00(\mp@subsup{x}{}{\wedge}0)
polynomial1: 4.00(\mp@subsup{x}{}{\wedge}4)+3.00(\mp@subsup{x}{}{\wedge}3)+6.00(\mp@subsup{x}{}{\wedge}2)+7.00(\mp@subsup{x}{}{\wedge}1)+8-00(\mp@subsup{x}{}{\wedge}0)
Enter polynomial2:
Enter polynomial2:
Enter degree of polynomial:4
Enter degree of polynomial:4
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of x:8
Enter Coefficient of x:8
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Enter Coefficient of }x=
Polynomial2: 6.0日(\mp@subsup{x}{}{\wedge}4)+7.00(\mp@subsup{x}{}{\wedge}3)+8.00(\mp@subsup{x}{}{\wedge}2)+9.00(\mp@subsup{x}{}{\wedge}1)+4.00(\mp@subsup{x}{}{\wedge}0)
Polynomial2: 6.0日(\mp@subsup{x}{}{\wedge}4)+7.00(\mp@subsup{x}{}{\wedge}3)+8.00(\mp@subsup{x}{}{\wedge}2)+9.00(\mp@subsup{x}{}{\wedge}1)+4.00(\mp@subsup{x}{}{\wedge}0)
Polynomial Sum:
Polynomial Sum:
10.0日(\mp@subsup{x}{}{\wedge}4)+10.00(\mp@subsup{x}{}{\wedge}3)+14.00(\mp@subsup{x}{}{\wedge}2)+16.00(\mp@subsup{x}{}{\wedge}1)+12.00(\mp@subsup{x}{}{\wedge}0)

```
10.0日(\mp@subsup{x}{}{\wedge}4)+10.00(\mp@subsup{x}{}{\wedge}3)+14.00(\mp@subsup{x}{}{\wedge}2)+16.00(\mp@subsup{x}{}{\wedge}1)+12.00(\mp@subsup{x}{}{\wedge}0)
```


## B.POLYNOMIAL MULTIPLICATION USING LINKED LIST

## PROGRAM

```
\#include <stdio.h>
\#include <stdlib.h>
```

```
struct node {
    int coeff;
    int expo;
    struct node* link;
};
struct node* insert(struct node* head, float co, int ex)
{
    struct node* temp;
    struct node* newP = malloc(sizeof(struct node));
    newP->coeff = co;
    newP->expo = ex;
    newP->link = NULL;
```

    if(head \(==\) NULL || ex > head->expo)
    \{
        newP->link = head;
        head = newP;
    \}
    else
    \{
        temp = head;
        while(temp->link != NULL \&\& temp->link->expo >= ex)
        temp = temp->link;
        newP->link = temp->link;
        temp->link \(=\) new ;
    \}
    return head;
    \}
struct node* create(struct node* head)
int $\mathbf{n}, \mathrm{i}$;
int coeff;
int expo;
printf("Enter the number of terms: ");
scanf("\%d", \&n);
for(i=0; i<n; i++)
\{
printf("Enter the coefficient: ", i+1);
scanf("\%d", \&coeff);
printf("Enter the exponent : ", i+1);
scanf("\%d", \&expo);
head = insert(head, coeff, expo);
\}
return head;
\}
void print(struct node* head)
\{
if(head $==$ NULL)
printf("No Polynomial.");
else \{
struct node* temp = head;
while(temp != NULL)
\{
printf("(\%dx^\%d)", temp->coeff, temp->expo);
temp $=$ temp->link;
if(temp!=NULL)
printf(" + ");

```
                else printf("\n");
        }
    }
}
void polyMult(struct node* head1, struct node* head2)
{
    struct node* ptr1 = head1;
    struct node* ptr2 = head2;
    struct node* head3 = NULL;
    if(head1 == NULL || head2 == NULL)
    {
        printf("Zero polynomial\n");
        return;
    }
    while(ptr1 != NULL)
    {
        while(ptr2 != NULL)
        {
        head3 = insert(head3, ptr1->coeff * ptr2->coeff, ptr1->expo + ptr2->expo);
        ptr2 = ptr2->link;
    }
        ptr1 = ptr1->link;
        ptr2 = head2;
    }
    printf("\nBefore simplification: \n");
    print(head3);
```

    struct node* ptr3 = head3;
    struct node* temp = NULL;
    ```
    while(ptr3->link != NULL) {
        if(ptr3->expo == ptr3->link->expo)
        {
        ptr3->coeff = ptr3->coeff + ptr3->link->coeff;
        temp = ptr3->link;
        ptr3->link = ptr3->link->link;
        free(temp);
        }
        else {
        ptr3 = ptr3->link;
        }
    }
    printf("\n After simplification: \n");
    print(head3);
}
void main()
{
    struct node* head1 = NULL;
    struct node* head2 = NULL;
    printf("Enter the first polynomial\n ");
    head1 = create(head1);
    printf("Enter the second polynomial\n ");
    head2 = create(head2);
    polyMult(head1, head2);
}
```


## OUTPUT

```
Enter the first polynomial
    Enter the number of terms: 3
Enter the coefficient: 2
Enter the exponent : 4
Enter the coefficient: 5
Enter the exponent : 3
Enter the coefficient: 6
Enter the exponent : 2
Enter the second polynomial
    Enter the number of terms: 4
Enter the coefficient: 2
Enter the exponent : 3
Enter the coefficient: 4
Enter the exponent : 5
Enter the coefficient: 3
Enter the exponent : 2
Enter the coefficient: 1
Enter the exponent : 0
Before simplification:
(8\mp@subsup{x}{}{\wedge}9)+(20\mp@subsup{x}{}{\wedge}8)+(4\mp@subsup{x}{}{\wedge}7)+(24\mp@subsup{x}{}{\wedge}7)+(6\mp@subsup{x}{}{\wedge}6)+(10\mp@subsup{x}{}{\wedge}6)+(15\mp@subsup{x}{}{\wedge}5)+(12\mp@subsup{x}{}{\wedge}5)+(2\mp@subsup{x}{}{\wedge}4)+(18\mp@subsup{x}{}{\wedge}4)+(5\mp@subsup{x}{}{\wedge}3)+(6\mp@subsup{x}{}{\wedge}2)
After simplification:
(8\mp@subsup{x}{}{\wedge}9) + (20x^8) + (28x^7) + (16x^6) + (27x^5) + (20x^4) + (5x^3) + (6x^2)
Process returned 10 (0xA) execution time : 28.438 s
Press any key to continue.
```


# 7.IMPLEMENTATION OF SORTING ALGORITHMS <br> BUBBLE, INSERTION, SELECTION,QUICK, MERGE \& HEAP SORT 

```
A. BUBBLE SORT
    PROGRAM
#include <stdio.h>
void bubbleSort(int array[], int size) {
    for (int step = 0; step < size - 1; ++step) {
for (int i=0; i < size - step - 1; ++i) {
    if (array[i] > array[i + 1]) {
    int temp = array[i];
    array[i] = array[i + 1];
    array[i + 1] = temp;
    }
    }
}
}
```

void printArray(int array[], int size) \{
for (int $\mathbf{i}=\mathbf{0} ; \mathbf{i}<$ size; + $\mathbf{i}$ ) \{
printf("\%d ", array[i]);
\}
printf("\n");
\}
void main()
\{
int arr[10];
int $i$;
printf("Enter elements in the array : $\backslash \mathrm{n}$ ");

```
for(i=0; i<10;i++)
```

\{
printf(" \%d-: ",i);
scanf("\%d", \&arr[i]);
\}
printf("\nElements in array are: ");
for (i=0; $i<10 ; i++)$
\{
printf("\%d ", arr[i]);
\}
printf("\n");
int size = sizeof(arr) / sizeof(arr[0]);
bubbleSort(arr, size);
printf("Sorted Array :\n");
printArray(arr, size);
\}

## OUTPUT

```
Enter elements in the array
    0-: 90
    1-: 67
    2-: 12
    3-: 11
    4-: 32
    5-: 34
    6-: 56
    7-: 4555
    8-: 43
    9-: 23
Elements in array are: 90 67 12 11 
Sorted Array :
11
```


## B. INSERTION SORT

## PROGRAM

\#include <stdio.h>

```
void printArray(int array[], int size) {
    for (int i=0; i < size; i++) {
    printf("%d ", array[i]);
    }
    printf("\n");
}
```

void insertionSort(int array[], int size) \{
for (int step = 1; step < size; step++) \{
int key = array[step];
int $\mathbf{j}=$ step -1 ;
while (key < array[j] \&\& j >= 0) \{
$\operatorname{array}[j+1]=\operatorname{array[j];}$
--j;
\}
$\operatorname{array}[\mathrm{j}+1]=$ key;
\}
\}
void main()
\{
int arr[5];
int i ;
printf("Enter elements in the array : $\backslash \mathrm{n} ")$;
for(i=0; i<5; $i++$ )
\{
printf(" \%d-: ",i);
scanf("\%d", \&arr[i]);
\}

```
printf("\nElements in array are: ");
for(i=0; i<5; i++)
{
    printf("%d ", arr[i]);
}
printf("\n");
int size = sizeof(arr) / sizeof(arr[0]);
insertionSort(arr, size);
printf("Sorted array in ascending order:\n");
printArray(arr, size);
}
```

OUTPUT

```
Enter elements in the array
    0-: 14
    1-: 52
    2-: 56
3-: 89
4-: 63
Elements in array are: 14 52 56 89 63
Sorted array in ascending order:
1 4 5 2 5 6 6 3 8 9
Process returned 10 (0xA) execution time : 7.902 s
Press any key to continue.
```


## C.SELECTION SORT

## PROGRAM

\#include <stdio.h>
void swap(int *a, int *b) \{
int temp $=$ *a;
*a $=$ *b;
*b = temp;
\}
void selectionSort(int array[], int size) \{
for (int step $=0 ;$ step $<$ size - 1; step++) \{ int min_idx = step;
for (int $\mathbf{i}=$ step $+1 ; i<\operatorname{size} ; i++$ )
if (array[i] < array[min_idx])
$\min$ idx $=i ;$
\}
swap(\&array[min_idx], \&array[step]);
\}
\}
void printArray(int array[], int size) \{
for (int $\mathrm{i}=0 ; \mathrm{i}$ < size; ++i) \{
printf("\%d ", array[i]);
\}
printf("\n");
\}
void main()
\{
int arr[5];
int $i ;$
printf("Enter elements in the array :\n");
for(i=0; i<5; i++)
\{
Signature Not Verified
Principal. VJEC
printf(" \%d-: ",i);

```
    scanf("%d", &arr[i]);
    }
    printf("\nElements in array are: ");
    for(i=0; i<5; i++)
    {
        printf("%d ", arr[i]);
    }
    printf("\n");
    int size = sizeof(arr) / sizeof(arr[0]);
    selectionSort(arr, size);
    printf("Sorted array in Acsending Order:\n");
    printArray(arr, size);
}
```


## OUTPUT

```
Enter elements in the array
0-: 10
1-: 0
2-: 9
3-: 3
4-: 56
Elements in array are: 10 0 9 9 3 56
Sorted array in Acsending Order:
0
Process returned 10 (0xA) execution time : 9.186 s
Press any key to continue.
```


## D. QUICK SORT

## PROGRAM

\#include <stdio.h>
void swap(int *a, int *b) \{
int $\mathrm{t}=$ *a;
*a $=$ *b;
*b $=\mathrm{t}$;
\}
int partition(int array[], int low, int high) \{
int pivot = array[high];
int $\mathbf{i}=($ low -1$)$;
for (int $\mathbf{j}=$ low; $\mathbf{j}$ < high; $\mathbf{j + +}$ ) \{
if (array[j] <= pivot) \{
i++;
swap(\&array[i], \&array[j]);
\}
\}
swap(\&array[i + 1], \&array[high]);
return (i+1);
\}
void quickSort(int array[], int low, int high) \{
if (low < high) \{
int pi = partition(array, low, high);
quickSort(array, low, pi-1);
quickSort(array, pi + 1, high);
\}
\}
void printArray(int array[], int size) \{
for (int $\mathbf{i}=\mathbf{0} ; \mathbf{i}<$ size; ++i) \{
printf("\%d ", array[i]);
\}
printf("\n");
\}
void main()

```
    int arr[5];
```

    int i ;
    printf("Enter elements in the array: : \(n\) ");
    for(i=0; i<5; i++)
    \{
            printf(" \%d-: ",i);
    scanf("\%d", \&arr[i]);
    \}
    printf("\nElements in array are: ");
    for(i=0; i<5; i++)
    \{
        printf("\%d ", arr[i]);
    \}
    printf("\n");
    int \(\mathbf{n}=\) sizeof(arr) / sizeof(arr[0]);
    printf("Unsorted Array\n");
    printArray(arr, n);
    quickSort(arr, 0, n-1);
    printf("Sorted array in ascending order: \n");
    printArray(arr, n);
    \}

## OUTPUT

```
Enter elements in the array
0-: 23
1-: 45
2-: 555
3-: 31
4-: 234
Elements in array are: 23 45 555 31 234
Unsorted Array
23}445\quad555 31 234
Sorted array in ascending order:
23}3314545234\quad55

\section*{E. MERGE SORT}

\section*{PROGRAM}
\#include <stdio.h>
void merge(int arr[], int p, int q, int r) \{
```

int n1 = q-p + 1;

```
int \(\mathrm{n} 2=\mathrm{r}-\mathrm{q}\);
int L[n1], M[n2];
for (int \(\mathbf{i}=\mathbf{0} ; \mathbf{i}<\mathbf{n 1} ; \mathbf{i + +})\)
    \(L[i]=\operatorname{arr}[p+i] ;\)
for (int \(\mathbf{j}=\mathbf{0} ; \mathbf{j}<\mathbf{n 2 ; ~ j + + )}\)
    \(M[j]=\operatorname{arr}[q+1+j] ;\)
int \(\mathbf{i}, \mathbf{j}, \mathbf{k} ;\)
\(\mathbf{i}=0 ;\)
j \(=\mathbf{0}\);
\(\mathrm{k}=\mathrm{p} ;\)
while (i<n1 \& \& \(<n 2\) ) \{
    if \((\mathrm{L}[\mathrm{i}]<=\mathrm{M}[\mathrm{j}])\) \{
        \(\operatorname{arr}[\mathrm{k}]=\mathrm{L}[\mathrm{i}] ;\)
        i++;
    \} else \{
        \(\operatorname{arr}[k]=M[j] ;\)
        j++;
    \}
    k++;
    \}
    while (i<n1) \{
    \(\operatorname{arr}[\mathrm{k}]=\mathrm{L}[\mathrm{i}] ;\)
    i++;
    k++;
\}
while (j < n2) \{
    \(\operatorname{arr}[\mathrm{k}]=\mathrm{M}[\mathrm{j}] ;\)
    j++;
    k++;
void mergeSort(int arr[], int I, int r) \{
\[
\text { if }(1<r)\{
\]
\[
\text { int } m=1+(r-1) / 2 ;
\]
mergeSort(arr, I, m);
\[
\text { mergeSort(arr, } m+1, r \text { ); }
\]
merge(arr, I, m, r);
\[
\}
\]
\[
\}
\]
void printArray(int arr[], int size) \{
\[
\text { for (int } i=0 ; i<\operatorname{size} ; i++ \text { ) }
\]
printf("\%d ", arr[i]);
printf("\n");
\[
\}
\]
void main()
\{
    int arr[5];
    int i ;
    printf("Enter elements in the array : \(\ \mathrm{n} ")\);
    for(i=0; i<5; i++)
    \{
            printf(" \%d-: ",i);
        scanf("\%d", \&arr[i]);
    \}
    printf("\nElements in array are: ");
    for(i=0; i<5; i++)
    \{
        printf("\%d ", arr[i]);
    \}
    printf("\n");
    int size = sizeof(arr) / sizeof(arr[0]);
mergeSort(arr, 0, size-1);
printf("Sorted array: \n");
printArray(arr, size);
\}


\section*{F. HEAP SORT}

\section*{PROGARM}

\section*{\#include<stdio.h>}
void Heapify(int a[],int n,int i)
\{
int temp;
int large \(=\mathbf{i}\);
int \(\mathrm{l}=\mathbf{2}\) * \(\mathbf{i}+\mathbf{1}\);
int \(\mathrm{r}=\mathbf{2 *}^{*} \mathbf{i}+\mathbf{2}\);
while(I<n \&\& a[I]>a[large])
large = 1 ;
while( \(\mathrm{r}<\mathrm{n}\) \&\& \(\mathrm{a}[\mathrm{r}]>\mathrm{a}[\) large] \()\)
large = r;
if(large ! \(\mathbf{i}\) )
\{
temp \(=\mathrm{a}[\mathrm{i}] ;\)
\(\mathrm{a}[\mathrm{i}]=\mathrm{a}\) [large \(]\);
a[large] = temp;
Heapify(a,n,large);
\}
\}
void heapsort(int a[],int size)
\{
int temp,i;
for(i=size/2-1;i>=0;i--)
Heapify(a,size,i);
for(int \(i=s i z e-1 ; i>=0 ; i--)\)
\{
temp \(=\mathrm{a}[0] ;\)
\(\mathrm{a}[0]=\mathrm{a}[\mathrm{i}] ;\)
\(\mathrm{a}[\mathrm{i}]=\) temp;
Heapify(a,size,0);
\}
```

}

```
void display(int a[],int size)
\{
printf("\nThe sorted array is:");
for(int i=0;i<size;++i)
\{
printf("\%d\t",a[i]);
\}
\}
void main()
\{
int size;
printf("\nEnter the size of array:");
scanf("\%d",\&size);
int a[size];
printf("\nEnter the elements of array:");
for(int i=0;i<size;i++)
\{
scanf("\%d",\&a[i]);
\}
heapsort(a,size);
display(a,size);
\}
OUTPUT


\section*{8 Implementation of searching algorithms - linear search, binary search.} PROGRAM
\#include<stdio.h>
int \(\mathbf{n}, \mathbf{s}, \mathbf{i}\);
int a[10];
void linear();
void binary();
int main()
\{
int \(c ;\)
printf("\n Enter the no of elements =");
scanf("\%d",\&n);
// int a[n];
printf("\nEnter the elements:\n");
for(i=0;i<n;i++)
\{
scanf("\%d",\&a[i]);
\}
while(1)
\{
printf("\n1.Linear search\n2.Binary search \(\backslash n 3\).exit \(\backslash n \backslash n\) enter your choice:");
scanf("\%d",\&c);
switch(c)
\{
case 1:linear();
break;
case 2:binary();
break;
case 3:return 0;
break;
default: printf("\nInvalid choice");
\}
\}
void linear()
\{
printf("\nEnter the element to be search :");
scanf("\%d",\&s);
int f=1,pos;
for(i=0;i<n;i++)
\{
if(a[i]==s)
\{
pos=i+1;
\}
else
\{
f=0;
\}
\}
\(i f(f=0)\)
\{
printf("\n element not found \(\backslash n\) ");
\}
else
\{
printf("\nelement fount at position \%d",pos);
\}
\}
void binary()
\{
printf("Enter the element to be search :");
scanf("\%d",\&s);
int \(\mathrm{fg}=0, \mathrm{~m}, \mathrm{f}=0, \mathrm{l}=\mathrm{n}\);
\(\mathrm{i}=0\);
do
\{
```

m=(f+l)/2;
if(a[m]==s)
{
fg=1;
printf("\nElement found at position:%d",++m);
}
else
{
if(s<a[m])
{
I=--m;
}
else
{
f=++m;
}
}
i++;
}while((fg!=1)\&\&(i<5));
if(fg==0)
{
printf("\n element not found\n");
}
}

```

```

1.Linear search
2.Binary search
3.exit
enter your choice:1
Enter the element to be search :24
element fount at position 7
1.Linear search
2.Binary search
3.exit
enter your choice:2
Enter the element to be search :12
Element found at position:1
1.Linear search
2.Binary search
3.exit

```

\section*{EEL202}

\section*{ELECTRICAL MACHINES LAB I}

\section*{MANUAL/OBSERVATION BOOK}


NAME \(\qquad\)
SEMESTER: \(\qquad\)
DEGREE/ BRANCH: \(\qquad\)
REGISTER NUMBER:

\section*{Prepared By}

TINTU GEORGE, Asso. Prof., EEE ATHIRA M. THOMAS, AP, EEE

\section*{DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING}

\section*{VIMAL JYOTHI ENGINNERING COLLEGE}

CHEMPERI, KANNUR - 670632

\section*{EEL202}

\section*{ELECTRICAL MACHINES LAB I}

\section*{LAB MANUAL AND OBSERVATION BOOK}

For
Fourth Semester B.Tech Electrical and Electronics Engineering Degree Courses (As per the APJ Abdul Kalam technological university Syllabus)
\[
2021-22
\]

Name of Student \(\qquad\)
Semester \& Branch \(\qquad\)

Roll No. \(\qquad\)
University Reg. No. \(\qquad\)

Certified that this is the bonafide record of the work done in the EEL202
Electrical Machines Lab I of Vimal Jyothi Engineering College Chemperi, Kannur by
\(M r . / M s\). \(\qquad\)

Date:
Place:
\begin{tabular}{ll} 
Staff in Charge & Head of the Department \\
Internal Examiner & External Examiner
\end{tabular}

\section*{Continues Internal Evaluation (CIE)}
\begin{tabular}{|c|c|c|c|}
\hline Attendance & \begin{tabular}{c} 
Regular Lab \\
work
\end{tabular} & Internal Test & Total \\
\hline 15 & \(\mathbf{3 0}\) & \(\mathbf{3 0}\) & \(\mathbf{7 5}\) \\
\hline & & & \\
\hline
\end{tabular}

Signature of the Faculty

\section*{Marks scored for Regular Lab Work and Attendance}
\begin{tabular}{|l|l|l|l|}
\hline \begin{tabular}{c} 
Sl. \\
No.
\end{tabular} & \multicolumn{1}{|c|}{ Name of experiment } & \begin{tabular}{c} 
Regular Lab \\
work \\
\((\mathbf{3 0})\)
\end{tabular} & \begin{tabular}{c} 
Attendance \\
\((\mathbf{1 5})\)
\end{tabular} \\
\hline 1 & \begin{tabular}{l} 
Open Circuit Characteristics of a DC Shunt \\
Generator
\end{tabular} & & \\
\hline 2 & Load Test on a DC Shunt Generator & & \\
\hline 3 & Brake Test on a DC Shunt Motor. & & \\
\hline 4 & Brake Test on a DC Series Motor & & \\
\hline 5 & Swinburne's Test on a DC Shunt Machine & & \\
\hline 6 & Hopkinson's test on a pair of DC machines & & \\
\hline 7 & Separation of losses in a DC shunt motor & & \\
\hline 8 & OC \& SC Tests on a Single Phase Transformer & & \\
\hline 9 & Direct Load Test on a Single Phase Transformer & & \\
\hline 10 & \begin{tabular}{l} 
Separation of Constant losses of a Single Phase \\
Transformer
\end{tabular} & & \\
\hline 11 & Sumpner's Test & & \\
\hline 12 & \begin{tabular}{l} 
Parallel Operation of two dissimilar Single Phase \\
Transformers
\end{tabular} & & \\
\hline Total & & & \\
\hline
\end{tabular}

\section*{INDEX}
\begin{tabular}{|l|l|l|}
\hline \begin{tabular}{l} 
Sl. \\
No.
\end{tabular} & Name of the Experiment & \begin{tabular}{l} 
Page \\
No.
\end{tabular} \\
\hline 1 & Open Circuit Characteristics of a DC Shunt Generator & \\
\hline 2 & Load Test on a DC Shunt Generator & \\
\hline 3 & Brake Test on a DC Shunt Motor. & \\
\hline 4 & Brake Test on a DC Series Motor & \\
\hline 5 & Swinburne's Test on a DC Shunt Machine & \\
\hline 6 & Hopkinson's test on a pair of DC machines & \\
\hline 7 & Separation of losses in a DC shunt motor & \\
\hline 8 & OC \& SC Tests on a Single Phase Transformer & \\
\hline 9 & Direct Load Test on a Single Phase Transformer & \\
\hline 10 & Separation of Constant losses of a Single Phase Transformer & \\
\hline 11 & Sumpner's Test & \\
\hline 12 & Parallel Operation of two dissimilar Single Phase Transformers & \\
\hline
\end{tabular}

\section*{SAFETY PRECAUTIONS IN ELECTRICAL LAB}
1. Wear tight dress in practical class for maximum safety
2. Use good quality footwear/ shoes in order to provide maximum resistance
3. Do not try to start any machines by which you don't know to stop
4. Understand the procedure completely before starting the work
5. Use proper tools for specific work and follow the actual steps to complete the work
6. Do not touch any apparatus which is wet
7. Do not touch switch boards, main switches, holder points etc with wet hands
8. Before putting the plug pin in socket put off the plug switch
9. Do not operate any electrical appliances at low voltage
10. Use correct size wire in order to carry the required current, without increment in temperature and fire
11.Give electric supply to the wiring system only after thorough verification

\section*{Preamble}

The purpose of this lab is to provide practical experience in operation and testing of DC machines and transformers.

\section*{COURSE OUTCOME}

After the successful completion of this course, the students will be able to
\begin{tabular}{|l|l|}
\hline CO 1 & \begin{tabular}{l} 
Analyze the performance of DC motors and DC generators by \\
performing load test.
\end{tabular} \\
\hline CO 2 & \begin{tabular}{l} 
Sketch the Open Circuit Characteristics of a self- excited DC shunt \\
generator and check conditions of voltage build up by performing \\
suitable experiment.
\end{tabular} \\
\hline CO 3 & \begin{tabular}{l} 
Develop equivalent circuit and predetermine their regulation and \\
efficiency by performing OC \& SC tests on transformer.
\end{tabular} \\
\hline CO 4 & \begin{tabular}{l} 
Analyze the efficiency and regulation of the transformer by performing \\
load test.
\end{tabular} \\
\hline CO 5 & \begin{tabular}{l} 
Analyze the efficiency of a DC machine when working as motor and \\
generator by conducting suitable test.
\end{tabular} \\
\hline CO 6 & \begin{tabular}{l} 
Examine the efficiency by performing Sumpner's test on two similar \\
transformers.
\end{tabular} \\
\hline
\end{tabular}

\section*{ASSESSMENT RUBRICS}

\section*{Continues Internal Evaluation (CIE)}

\section*{Regular Lab Work Assessment Rubrics (30)}
\begin{tabular}{|c|c|c|c|c|}
\hline \begin{tabular}{c} 
Preliminary \\
work
\end{tabular} & \begin{tabular}{c} 
Implementing the \\
work/Conducting \\
the experiment
\end{tabular} & \begin{tabular}{c} 
Calculations, result \\
and inference
\end{tabular} & Viva voce & \begin{tabular}{c} 
Record \\
Submission
\end{tabular} \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline
\end{tabular}
\begin{tabular}{|c|c|c|c|c|}
\hline CATEGORY & 5 & 4 & 2 & 1 \\
\hline \begin{tabular}{l}
Preliminary work - \\
Drawings/ Diagrams
\end{tabular} & Clear, accurate diagrams are included and make the experiment easier to understand. Diagrams are labeled neatly and accurately. & Diagrams are included and are labeled neatly and accurately. & Diagrams are included and are labeled. & Needed diagrams are missing OR are missing important labels. \\
\hline \begin{tabular}{l}
Implementing \\
The \\
work/Conduct ing the experiment
\end{tabular} & Procedures are listed in clear steps and studied well. Experiment is conducted as per the correct procedure. & Procedures are listed in a logical order, but steps are not correctly studied. Conducted the experiment & Procedures are listed but are not in a logical order or are difficult to follow and not studied. Not done in a proper way. & Procedures do not accurately list the steps of the experiment. Not studied and not conducted well \\
\hline \begin{tabular}{l}
Calculations - \\
Result and Inference
\end{tabular} & All calculations are shown and the results are correct, inference is made and labeled appropriately. & Some calculations are shown and the results are correct and labeled appropriately. & Some calculations are shown and the results labeled appropriately. & No calculations are shown OR results are inaccurate or mislabeled. \\
\hline \multirow[t]{2}{*}{Record Submission} & Completed all the work on time and submitted & Completed all the work, submitted with one day delay & Not properly completed and submitted late & Late submission \\
\hline & 10 & 8 & 6 & 3 \\
\hline Viva voce & Excellent knowledge related to the experiment and answered all questions very clearly & Good knowledge related to the experiment and answered some questions very clearly & Average knowledge related to the experiment and answered Si some questions & Poor knowledge related to the experiment and nature Notukereitied questi ss very incipáprlvJEC \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}


\section*{MACHINE DETAILS:}
\(\qquad\)

\section*{OPEN CIRCUIT CHARACTERISTICS OF A SELF EXCITED DC SHUNT GENERATOR}

\section*{AIM}

To obtain the open circuit characteristics of self excited DC shunt generator at rated speed.

\section*{OBJECTIVE:}

To
a) Predetermine the OCC at different speeds
b) Determine the critical field resistance
c) Obtain maximum voltage built up with given shunt field resistance
d) Obtain critical speed for a given shunt field resistance

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|l|l|l|l|}
\hline Sl No & Equipment & Specification & Quantity \\
\hline 1 & Ammeter & \((0-1)\) A, MC & 1 no \\
\hline 2 & Voltmeter & \((0-300)\) V, MC & 1 no \\
\hline 3 & Rheostat & \(570 \Omega, 1.2 \mathrm{~A}\) & 2 no \\
\hline 4 & Switch & SPST & 1 no \\
\hline 5 & Tachometer & & 1 no \\
\hline
\end{tabular}

\section*{PRINCIPLE}

The open circuit characteristics give the variation of generated voltage (E) with field current ( \(\mathrm{If}_{\mathrm{f}}\) at a constant speed.
\[
\mathrm{E}=(\Phi \mathrm{Z} \mathrm{~N} / 60) *(\mathrm{P} / \mathrm{A})
\]
where \(\phi\) is the flux/pole in Weber, \(N\) is the speed of the machine in rpm, Z is the number of conductors, P is the number of poles, and A is the number of parallel paths. Therefore \(\mathrm{E} \alpha \phi \mathrm{N}\) When speed is constant, generated voltage is proportional to field flux. When the field current is zero, a small residual flux is present in the machine and a small voltage is generated when \(I_{f}\) is zero. As the field current is increased, the voltage increases linearly with \(\mathrm{I}_{\mathrm{f}}\). At some value of If magnetic circuit starts getting saturated. In the saturated region, voltage increases only slightly with increase in field current. The generated voltage is directly proportional to speed can be obtained from the test curve at rated speed.

Open circuit characteristics, O.C.C is a curve showing the relationship between No load e.m.f ( \(\mathrm{E}_{\mathrm{o}}\) ) generated in the armature and shunt field current ( \(\mathrm{I}_{\mathrm{f}}\) ). The curve is notignature Not Verified, this is due to residual magnetism present in the poles. So even when the field curr_f is zero, there is some no load emf generated in the armature due to residual flux. Principal.VJEC

\section*{OBSERVATIONS:}

Residual emf \(=\)
\begin{tabular}{|l|l|c|c|}
\hline SI. No & If \((A)\) & \begin{tabular}{c} 
E1 at the rated rpm \\
(V) i.e. 1500 rpm
\end{tabular} & \begin{tabular}{c}
\(\mathrm{E}_{1}\) at 80 \% rated \\
rpm (V) i.e. \\
1200rpm
\end{tabular} \\
\hline & & & \\
& & & \\
& & & \\
\hline
\end{tabular}

\section*{SAMPLE CALCULATION:}

\section*{(a) To determine the critical field resistance at rated speed}

Draw a tangent to straight line portion of the OCC passing through the origin. Then critical field resistance \(R_{c}\) at rated \(R P M=\) slope of the tangent. From the graph, \(R_{c}=\{A B / O A\}=\)

The first portion in the curve is practically a straight line due to the fact that as 'If' increases, the induced emf ' \(\mathrm{E}_{\mathrm{a}}\) ' increases linearly, until the magnetic core gets saturated. Then curve become non-linear. This is due to saturation of poles at higher flux density. That is, when the core gets saturated, further increase in field current does not change the emf much. Critical Resistance is the value of resistance in the field circuit where the generator will just excite. (Voltage build up begins) It is given by the slope of the tangent drawn to the linear portion of the magnetization curve, from the origin.

\section*{Maximum voltage build-up with given shunt field}

Conditions for voltage build up in a d.c shunt generator
a) There must be some residual magnetism in the poles.
b) Shunt field resistance must be less than critical resistance.
c) For the given direction of rotation, the shunt field coils should be properly connected to the armature terminals.
To find the maximum voltage build up:- With the residual flux, the voltage starts building up \(\left(\mathrm{E}_{\mathrm{a}} \propto \Phi\right)\), as a result armature current increases which in turn increases field current and hence generated voltage. The voltage will continue to build up till the point of intersection of Field Resistance Line and Magnetization curve (OCC) of DC Shunt Generator. Beyond point of intersection of Field Resistance Line and OCC, the voltage won't build up as in that case the generated voltage \(\mathrm{E}_{\mathrm{a}}\) will not be able to drive the required field current. Thus the stable point at which the voltage will remain fix is the voltage Ea corresponding to point of intersection of Field Resistance Line and OCC. For that, draw the line for shunt field resistance having a slope \(=\mathrm{R}_{\text {sh }}\). The no-load voltage corresponding to the meeting point of \(\mathrm{R}_{\text {sh }}\) with the O.C.C. is the maximum voltage build up value.
Critical speed is the minimum speed of the generator such that the generator will just excite.

\section*{PROCEDURE}

The connections are done as per circuit diagram. The rheostat in the shunt field circuit of the motor \(\left(\mathrm{Rh}_{1}\right)\) is kept in minimum position and that of the generator \(\left(\mathrm{Rh}_{2}\right)\) is kept in the maximum position. The supply is given and the motor is started using three-point starter. The SPST switch should be kept open during the starting of the generator. Adjust \(\mathrm{Rh}_{1}\) to run the motor - generator set at rated speed and in proper direction. The generated emf due to residualmagnetism is noted by using the voltmeter. Now close the SPST switch. Adjust \(\mathrm{Rh}_{2}\) suitably for different values of field current \(\mathrm{I}_{\mathrm{f}}\) (say \(0.05 \mathrm{~A}, 0.10 \mathrm{~A} 0.15 \mathrm{~A}, 0.20 \mathrm{~A} \ldots\) ) and note the corresponding generated voltages up to \(125 \%\) of the rated voltage. (Care should be taken that speed should not change during the course of the experiment and \(\mathrm{Rh}_{2}\) should be adjusted only in one direction i.e. from maximum to minimum otherwise the readings will be incorrect).

\section*{PRECAUTIONS:}
- The field rheostat of motor should be in minimum resistance position at the time of starting and stopping the machine.
- The field rheostat of generator should be in maximum resistance position at the time of starting and stopping the machine.
- Do not stop the machine by putting its starter arm.
- SPST switch is kept open during starting and stopping the machine Principall.VJEC \(^{\text {- }}\)

\section*{OCC OF DC SHUNT GENERATOR:}

Scale

X-axis, \(1 \mathrm{~cm}=0.05 \mathrm{~A}\)

Y -axis , 1cm=10 V

(b) To predetermine the OCC at \(80 \%\) of the rated speed

For the same field current the induced voltage is found by using the relation
\(E_{1} / E_{2}=N_{1} / N_{2}\)

Speed of the motor
\(\mathrm{N}_{1}=\) Field current \(\mathrm{I}_{\mathrm{f}}=\)

Generated emf \(E_{1}=\)

So, \(\mathrm{E}_{2}=\mathrm{E}_{1} * N_{2} / N_{1}=\)
Then the predetermined OCC at given \% of the rated speed is plotted.

\section*{(c) To determine voltage build up for \(\mathbf{2 5 0} \mathbf{~ o h m}\) field resistance}

For example, for drawing the \(250 \Omega\) field resistance line passing through the origin o(0,0) ,assume a suitable value of current (I) to get \(\mathrm{V}=250 \mathrm{I}\). Then the second point will be \(\mathrm{F}(\mathrm{I}, \mathrm{V})\). This line intersects OCC at point R.Then OD gives the maximum voltage built up for \(250 \Omega\) field resistance

\section*{(d) To find the critical speed for given field resistance}

Draw the line corresponding to the given field resistance in the graph.
Critical speed, \(\mathrm{Nc}=\mathrm{N}^{*} A C / A B \mathrm{rpm}=\)

N is the rated speed, in rpm.

VIVA

\section*{RESULT:}

Open circuit characteristics of the given DC shunt machine at rated rpm, and at given \% of the rated rpm are plotted.

Critical filed resistance at rated \(\mathrm{rpm} \mathrm{R}_{\mathrm{c}}=\)

The maximum voltage build up for given field resistance \(=\)

The critical speed for given field resistance \(=\)

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & & & & \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}

\(10 \mathrm{~A}, 220 \mathrm{~V}\)
MACHINE DETAILS:

MEASUREMENT OF ARMATURE RESISTANCE:

\(\qquad\)

\section*{LOAD TEST ON DC SHUNT GENERATOR}

\section*{AIM}

To conduct load test on DC shunt generator

\section*{OB,JECTIVES:}

To
a) Determine the external and internal characteristics of the given DC shunt generator

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|l|l|l|l|}
\hline Sl No & Equipments & Specification & Quantity \\
\hline 1 & Ammeter & \((0-2 \mathrm{~A}) \mathrm{MC}\) & 1 no \\
\hline 2 & Ammeter & \((0-20 \mathrm{~A}) \mathrm{MC}\) & 1 no \\
\hline 3 & Ammeter & \((0-5 \mathrm{~A}) \mathrm{MC}\) & 1 no \\
\hline 4 & Voltmeter & \((0-30 \mathrm{~V}) \mathrm{MC}\) & 1 no \\
\hline 5 & Voltmeter & \((0-300 \mathrm{~V}) \mathrm{MC}\) & 1 no \\
\hline 6 & Rheostat & \(570 \Omega, 1.2 \mathrm{~A}\) & 2 no \\
\hline 7 & Rheostat & \(45 \Omega, 5 \mathrm{~A}\) & 1 no \\
\hline 8 & Switch & DPST & 1 no \\
\hline 9 & Loading Rheostat & & 1 no \\
\hline 10 & Tachometer & & 1 no \\
\hline
\end{tabular}

\section*{PRINCIPLE}

For a DC shunt generator,
\(\mathrm{E}=\mathrm{V}+\mathrm{I}_{\mathrm{a}} \mathrm{R}_{\mathrm{a}}\)
\(\mathrm{I}_{\mathrm{a}}=\mathrm{I}_{\mathrm{L}}+\mathrm{I}_{\mathrm{f}}\)
where E is the induced emf, V is the terminal voltage, \(\mathrm{I}_{\mathrm{a}}\) is the armature current and \(\mathrm{I}_{\mathrm{L}}\) is the load current. External characteristics is the plot of terminal voltage with load current at constant field resistance and speed .As the load on the machine is varied ,the terminal voltage drops. It is due to
(1) The drop in voltage across the armature resistance ie, \(I_{a} R_{a}\) drop.
(2) Armature reaction: the air gap flux decreases which will reduce the induced emf,E.
(3) The drop in terminal voltage due to (1) and (2) results in a decreased field current which further reduces the induced emf, E .

Signature Not Verified
Internal characteristics are the plot of induced voltage (E) with armature current(I) It takes into account the drop due to armature reaction and armature voltage drophtnfapaif. \&fted from external characteristics as from equations (1) and (2).

\section*{OBSERVATIONS:}
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline Sl. No & \[
\begin{gathered}
\mathbf{V} \\
(\mathbf{V})
\end{gathered}
\] & \[
\begin{gathered}
\mathbf{I}_{\mathbf{f}} \\
(\mathbf{A})
\end{gathered}
\] & \[
\begin{gathered}
\mathbf{I}_{\mathbf{L}} \\
(\mathbf{A}) \\
\hline
\end{gathered}
\] & \[
\begin{gathered}
\mathbf{I a}=\mathbf{I}_{\mathbf{f}}+\mathbf{I}_{\mathbf{L}} \\
(\mathbf{A}) \\
\hline
\end{gathered}
\] & \[
\begin{gathered}
\mathbf{I}_{\mathbf{a}} \mathbf{R a}_{\mathbf{a}} \\
(\mathbf{V}) \\
\hline
\end{gathered}
\] & \[
\begin{gathered}
\mathrm{E}=\mathrm{V}+\mathrm{IaRa} \\
(\mathrm{~V})
\end{gathered}
\] & \[
\begin{gathered}
\text { Ea= Eo- E } \\
(\mathrm{V}) \\
\hline
\end{gathered}
\] \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
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\hline & & & & & & & \\
\hline & & & & & & & \\
\hline
\end{tabular}

\section*{ARMATURE RESISTANCE MEASUREMENT:}
\begin{tabular}{|c|c|c|c|}
\hline Sl.No. & \begin{tabular}{c} 
V \\
(V)
\end{tabular} & \begin{tabular}{c} 
I \\
(A)
\end{tabular} & \begin{tabular}{c} 
R=V/I \\
(ohm)
\end{tabular} \\
\hline & & & \\
& & & \\
& & & \\
& & & \\
\hline
\end{tabular}

Mean resistance \(=\)

Voltage due to armature reaction \(\mathrm{E}_{\mathrm{a}}=\mathrm{E}_{0}-\mathrm{E}\)
Armature reaction curve is the plot \(\mathrm{E}_{\mathrm{a}}\) vs \(\mathrm{I}_{\mathrm{a}}\)

\section*{PROCEDURE}

The connections are done as per the connection diagram. The rheostat in the shunt field circuit of the motor \(\left(\mathrm{Rh}_{1}\right)\) is kept minimum position and that of the generator \(\left(\mathrm{Rh}_{2}\right)\) is kept maximum position .The supply is given and the motor is started using three point starter. Adjust \(\mathrm{Rh}_{1}\) to run the motor -generator set at rated speed and in proper direction. Adjust \(\mathrm{Rh}_{2}\) suitably to no load attain the no load voltage by giving its rated excitation. Then close the switch and load the generator in steps until the full load current is reached .At this instant a slight increase in the load results in decrease of load current .Continue the experiment until the voltage generated becomes zero. Keep the speed constant throughout the experiment. Also measure the armature resistance of the DC shunt generator.

\section*{EXTERNAL AND INTERNAL CHARACTERISTICS:}


\section*{SAMPLE CALCULATION:}

No load voltage \(\mathrm{E}_{0}=\)
Terminal voltage \(\mathrm{V}=\)
Field current lf=

Load current ll=

Armature current \(\mathrm{l}_{\mathrm{a}}=\mathrm{If}+\mathrm{II}\)
Induced voltage E= V+ laRa =
\(\mathrm{Ea}=\mathrm{E} 0-\mathrm{E}=\)

VIVA

\section*{RESULT}

The load test is conducted on given dc shunt machine and external and internal characteristics are plotted.

\section*{ASSESSMENT RUBRICS}


\section*{CIRCUIT DIAGRAM}


\section*{MACHINE DETAILS}

Sample Graphs:
Torque Vs Armature current


Speed Vs Torque


Performance characteristics:


\section*{Experiment No: 3}

Date:

\section*{BRAKE TEST ON DC SHUNT MOTOR}

\section*{AIM}

To conduct brake test on DC Shunt Motor

\section*{OB.JECTIVE}

To
1. Plot Performance Characteristics
2. Plot Electrical Characteristics (Torque Vs Armature current)
3. Plot Mechanical Characteristics (Speed Vs Torque)

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|l|c|c|}
\hline No & Equipments & Specification & Quantity \\
\hline 1 & Ammeter & \(0-2 \mathrm{~A} \mathrm{MC}\) & 1 \\
\hline 2 & Voltmeter & \(0-300 \mathrm{~V}\) MC & 1 \\
\hline 3 & Ammeter & \(0-20 \mathrm{~A} \mathrm{MC}\) & 1 \\
\hline 4 & Rheostat & \(35 \Omega, 1.1\) A & 1 \\
\hline 5 & SPST & Switch & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

DC Machines can be tested by three different methods namely Direct Method, Indirect Method and Regenerative Method. Direct Method of testing of DC Machine, also known as Brake Test. Direct method is suitable for small DC machines. In Direct Method, the DC machine is subjected to rated load and the entire output power is wasted.

A belt around the air-cooled pulley has its end attached to the spring balance S1 and S2. Using belt tightening hand wheels H 1 and H 2 , the load of motor is adjusted to its rated value. Assuming the spring balance to be calibrated in kilogram, then rated load on the DC motor is given as
Motor Output Power \(=\) Torque x Angular Speed
\[
=\text { (Force } \times \text { Radius) } \mathrm{x} \text { Angular Speed }
\]

As the torque because of force F1 and F2 are opposing each other, therefore net torque will be subtraction of torque because of F1 and F2.
Therefore,
Motor Output \(=\omega\left(S_{1}-S_{2}\right) \times \mathrm{rx} 9.8\) Watt
Principall VJEC Power input to the DC Motor \(=\mathrm{V}^{*} \mathrm{I}_{\mathrm{L}}\)

\section*{TABULAR COLOUMN}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{Voltage (V)} & \multirow[t]{2}{*}{\begin{tabular}{l}
IL \\
(A)
\end{tabular}} & \multirow[t]{2}{*}{Speed (N) (rpm)} & \multicolumn{2}{|l|}{Balance} & \multirow[t]{2}{*}{\[
\begin{aligned}
& \text { Torque } \\
& \text { in } \mathrm{N}-\mathrm{M} \\
& \mathrm{~T}=\left(\mathrm{S}_{1}-\mathrm{S}_{2}\right) \mathrm{rg}
\end{aligned}
\]} & \multirow[t]{2}{*}{\[
\begin{aligned}
& \mathrm{O} / \mathrm{p}= \\
& 2 \pi \mathrm{NT} / 60
\end{aligned}
\]} & \multirow[t]{2}{*}{I/P=V IL} & \multirow[t]{2}{*}{\[
\begin{aligned}
& \eta= \\
& (\mathrm{o} / \mathrm{p}) /(\mathrm{i} / \mathrm{p})
\end{aligned}
\]} \\
\hline & & & \(\mathrm{S}_{1}\) & \(\mathrm{S}_{2}\) & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline
\end{tabular}
\(\mathrm{r}=\) radius of brake drum
\(\mathrm{g}=\) acceleration due to gravity

\section*{SAMPLE CALCULATIONS}

Perimeter, \(2 \pi \mathrm{r}=\)
r=
\(\mathrm{V}=\)
\(\mathrm{I}_{\mathrm{L}}=\)
\(\mathrm{N}=\)
\(\mathrm{S}_{1}=\)
\(\mathrm{S}_{2}=\)
\(\mathrm{T}=\left(\mathrm{S}_{1}-\mathrm{S}_{2}\right) \mathrm{rg}=\)
Output \(=\frac{2 \pi N T}{60}=\)
Input \(=V \mathrm{I}_{\mathrm{L}}=\)
Efficiency \((\eta)=\frac{\text { output }}{\text { Input }} \times 100=\)

Thus the efficiency of DC Motor can be calculated as below.
Efficiency \(=\) Output \(/\) Input
\[
=\left[\omega\left(S_{1}-S_{2}\right) \times \mathrm{rx} 9.8 \mathrm{Watt}\right] / \mathrm{VI}_{\mathrm{L}}
\]

\section*{PROCEDURE}
1) Circuit is connected as per the circuit diagram.
2) The motor Rheostat is kept at minimum position.
3) Ensure that initially there is no load on the motor.
4) Machine is started using the three-point starter and the speed of the motor is adjusted torated value by varying the motor field rheostat.
5) Note down the readings at no load.
6) Load the motor by tightening the belt on the pulley and record the readings of all the meters, speed and the readings of both the spring balances.
7) Repeat step 6 by increasing the load on the motor in steps, till the rated current of the motor is obtained.
8) Remove the load gradually and then bring the motor rheostat starting position (minimum) before stopping the motor by switching off the supply.

\section*{PRECAUTIONS:}
1. DC shunt motor should be started and stopped under no load condition.
2. Field rheostat should be kept in the minimum position.
3. Brake drum should be cooled with water when it is under load.

\section*{RESULT}

Conducted load test on DC shunt motor and plotted the following characteristics.
- Torque Vs Armature current (electrical characteristics)
- Speed Vs Torque (Mechanical characteristics)
- Performance curves

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline \begin{tabular}{c} 
Preliminary \\
Work
\end{tabular} & \begin{tabular}{c} 
Implementing the \\
Work/Conducting \\
the Experiment
\end{tabular} & \begin{tabular}{c} 
Calculations, \\
Result and \\
Inference
\end{tabular} & Viva voce & \begin{tabular}{c} 
Record \\
Submission
\end{tabular} \\
\hline \(\mathbf{5}\) & \(\mathbf{5}\) & \(\mathbf{5}\) & \(\mathbf{1 0}\) & \(\mathbf{5}\) \\
\hline \begin{tabular}{c} 
Total Marks \\
scored \\
\(\&\)
\end{tabular} & \multicolumn{4}{|l|}{} \\
\begin{tabular}{c} 
Signature of \\
Faculty
\end{tabular} & \multicolumn{4}{l|}{} \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}


\section*{MACHINE DETAILS:}

SAMPLE GRAPHS:
Speed Vs Torque (mechanical chara)
Torque Vs Armature Current (electrical chara)



Performance characteristics:

\(\qquad\)

\section*{BRAKE TEST ON DC SERIES MOTOR}

\section*{AIM}

To conduct a load test on a dc series motor for obtaining its performance characteristics.

\section*{OB.JECTIVES:}

To plot the following characteristics
a) Performance characteristics
b) Electrical characteristics
c) Mechanical characteristics.

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|l|l|l|l|}
\hline Sl No & Equipments & Specification & Quantity \\
\hline 1 & Ammeter & \((0-20 \mathrm{~A})\), MC & 1 \\
\hline 2 & Voltmeter & \(90-250 \mathrm{~V})\), MC & 1 \\
\hline 3 & Tachometer & \(0-2000 \mathrm{rpm}\) & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

The motor is loaded directly by a belt placed on a water cooled pulley mounted on the shaft of the motor. The desired load is put on the motor by tightening the belt. Tension applied in the belt is measured by using spring balance.

Input power \(\mathrm{P}_{\text {in }}=\mathrm{V}_{\mathrm{L}} * \mathrm{I}_{\mathrm{a}}\)
Torque \(=\left(\mathrm{S}_{1}-\mathrm{S}_{2}\right) * \mathrm{r}^{*} * \mathrm{~g}\)
Where
\(\mathrm{S}_{1}\) is the tension on the tight side of the brake in kg
\(\mathrm{S}_{2}\) is the tension on the slack side of the brake in kg
\(r\) is the radius of the brake drum in \(m\)
g is the gravitational constant \(=9.81 \mathrm{~kg} / \mathrm{m}^{2}\)
Output Power \(P_{\text {out }}=\frac{2 \pi N T}{60}\)
\% efficiency, \(\quad \eta=\frac{P_{\text {out }}}{P_{\text {to }}} \times 100\)
Speed of a series motor, \(N=\frac{V-I_{a}\left(R_{a}+R_{s e}\right)}{K \phi}=\frac{E_{b}}{K \phi}\)

\section*{TABULAR COLOUMN}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|}
\hline \[
\begin{aligned}
& \text { Sl } \\
& \text { No }
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{V}_{\mathbf{L}} \\
& (\mathbf{V})
\end{aligned}
\] & \begin{tabular}{l}
Ia \\
(A)
\end{tabular} & \[
\begin{aligned}
& \mathrm{N} \\
& \text { rpm }
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{S}_{1} \\
& \mathbf{k g}
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{S}_{2} \\
& \mathbf{k g}
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{S}_{1}-\mathbf{S}_{2} \\
& \mathrm{~kg}
\end{aligned}
\] & \[
\begin{aligned}
& \mathrm{T} \\
& \mathrm{Nm}
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{P}_{\mathbf{i}} \\
& \mathbf{W}
\end{aligned}
\] & \[
\begin{aligned}
& \mathbf{P}_{\mathbf{o}} \\
& \mathbf{W}
\end{aligned}
\] & \(\eta(\%)\) \\
\hline 1 & & & & & & & & & & \\
\hline 2 & & & & & & & & & & \\
\hline 3 & & & & & & & & & & \\
\hline 4 & & & & & & & & & & \\
\hline 5 & & & & & & & & & & \\
\hline 6 & & & & & & & & & & \\
\hline 7 & & & & & & & & & & \\
\hline 8 & & & & & & & & & & \\
\hline
\end{tabular}

\section*{SAMPLE CALCULATION:}

Perimeter of the brake drum, \(=x=\)

Radius of the brake drum,
\(R=\frac{x}{2 \pi}=\)

Line Voltage \(=\mathrm{VL}=\)

Line current = la=

Speed \(=\mathrm{N}=\)

Brake drum loads \(=\) S1 =

Where \(\mathrm{I}_{\mathrm{a}}\) is the armature current, \(\mathrm{R}_{\mathrm{a}}\) is the armature resistance, \(\mathrm{R}_{\text {se }}\) is the series fieldresistance, \(\emptyset\) is the flux per pole and \(N\) is the speed in rpm.

A series motor should never run without load. In case of series motor, if the load is absent, load current and hence armature and field current are minimum (armature and field are in series). If the field current is very low field flux is also low hence the speed will dangerously high (speed is inversely proportional to field flux). A very high speed may destroy the machine due to centrifugal force set up inside motor.

Series motor starts with two point starter to reduce the starting current.
In a series motor field flux \(\emptyset\) is directly proportional to \(I_{a}\) upto the point of magnetic saturation. The torque \(T \alpha \emptyset I_{a}\) ie T \(\alpha \mathrm{I}_{\mathrm{a}}{ }^{2}\)
Hence before saturation \(T\) vs. \(I_{a}\) curve will be parabolic.
Variation of speed can be deduced from the formula \(N \alpha E_{b} / \varnothing\). Speed torque curve will be a rectangular hyperbola. With increased \(\mathrm{I}_{\mathrm{a}}, \varnothing\) also increases. Hence speed varies inversely as the armature current. It is found that when speed is high, torque is low and vice versa.
Maximum load calculation
Max Power input \(=\mathrm{V}_{\text {rated }} * \mathrm{I}_{\text {rated }}\)

\section*{PROCEDURE}

Connections are done as per the circuit diagram. Apply the calculated load, before starting the motor.

Switch ON the DC supply, cut off the starter resistance gradually within 2-5 seconds by moving the starter arm. Adjust the belt load to the rated load current. Readings of ammeter, voltmeter and spring balance are taken. Measure the speed of the motor using a tachometer. Gradually decrease the load, and take different sets of readings for different load currents, up to half the full load.

\section*{PRECUATIONS:}
(1) Never start, run, or stop a dc series motor without sufficient load
(2) Never stop a dc machine by pulling back the starter arm.
(3) While conducting load test avoid the overheating of brake drum by pouring water in the brake drum.
\[
\begin{array}{r}
S_{2}= \\
\left(S_{1}-S_{2}\right)=
\end{array}
\]

Radius of the brake drum, \(R=\)
Torque, \(\quad T=\left(S_{1}-S_{2}\right) \times R \times g=\)

Input power, \(P_{\text {in }}=V_{L} \times I_{a}=\)
\[
\text { Out power } \mathrm{P}_{\text {out }}=\frac{2 \pi N T}{60}=
\]
\[
\% \text { of efficiency }, \eta=\frac{P_{\text {out }}}{P_{\text {in }}} \times 100=
\]
\[
\text { Power output }=\frac{2 \pi N \times\left(S_{1}-S_{2}\right) \times R \times g}{60}
\]
\[
\text { Maximum load }\left(S_{1}-S_{2}\right)=\frac{V_{\text {rated }} \times I_{\text {rated }} \times 60}{2 \pi N \times R \times g}
\]
\[
=
\]
\[
=
\]

Error \(=\)
Maximum load \(=\)

\section*{RESULT}

Conducted load test on DC series motor and plotted the following characteristics.
- Torque Vs Armature current (electrical characteristics)
- Speed Vs Torque (Mechanical characteristics)
- Performance curves

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & \multicolumn{4}{|l|}{} \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}


CIRCUIT DIAGRAM TO FIND ARMATURE RESISTANCE:


\section*{MACHINE DETAILS:}

Principal.VJEC

\section*{SWINBURNE'S TEST ON D.C SHUNT MACHINE}

\section*{AIM}

To perform Swinburne's test on the given D.C machine and predetermine the efficiency at any desired load both as motor and as generator.

\section*{OB,JECTIVE:}

To predetermine the armature current and percentage efficiency when the machine operates as a motor and as a generator for various load conditions and plot efficiency Vs output curves.

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|l|l|l|l|}
\hline Sl.No. & \multicolumn{1}{|c|}{ Equipments } & \multicolumn{1}{|c|}{ Specification } & \multicolumn{1}{c|}{ Quantity } \\
\hline 1 & Ammeter & MC, \(0-2 \mathrm{~A}, 0-1 \mathrm{~A}, 0-10 \mathrm{~A}\) & 3 \\
\hline 2 & Voltmeter & MC, \(0-30 \mathrm{~V}, 0-300 \mathrm{~V}\) & 2 \\
\hline 3 & Rheostat & WW, \(370 \Omega / 2 \mathrm{~A}\) & 1 \\
\hline 4 & Tachometer & Digital, \(0-10000 \mathrm{rpm}\) & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

This test is to find out the efficiency of the machine. It is a simple indirect method in which losses are determined separately and from their knowledge, efficiency at any desired load can be predetermined. The only test needed is no-load test. This test cannot be performed on DC series motor. The machine is run as a no-load shunt motor at rated speed and with a rated terminal voltage. However, this test is applicable to those machines in which flux is practically constant. The constant losses in a dc shunt machine \(=\mathrm{W}_{\mathrm{c}}=\) stray losses (magnetic \& mechanical losses) +shunt field copper losses.

\section*{SAMPLE GRAPH:}


\section*{OBSERVATIONS:}
\begin{tabular}{|c|c|c|c|c|}
\hline \begin{tabular}{c} 
Voltmeter \\
(V)
\end{tabular} & \begin{tabular}{c} 
Ammeter \\
Reading \\
\(\mathrm{I}_{\text {Lo }}\) \\
(A)
\end{tabular} & \begin{tabular}{c} 
Ammeter \\
Reading \\
\(\mathrm{I}_{\text {sh }}\) \\
(A)
\end{tabular} & Speed (rpm) & \(\mathrm{W}_{\mathrm{c}}=\mathrm{VI}_{\mathrm{Lo}}-\mathrm{I}_{\mathrm{Sh}}{ }^{2} \mathrm{R}_{\mathrm{a}}\) \\
\hline & & & & \\
\hline & & & & \\
& & & & \\
\hline
\end{tabular}

\section*{PROCEDURE:}
1) Make all the connections are as per the circuit diagram.
2) Keep the field rheostat in minimum resistance position.
3) Excite the motor with \(\mathbf{2 2 0 V}\), DC supply by closing the DPST switch and start the motor by moving the handle of 3-point starter from OFF to ON position.
4) By adjusting the filed rheostat obtain the rated excitation and then by adjusting the armature rheostat, obtain the rated speed of the motor.
5) The necessary calculations to find efficiency of machine as motor \& generator at any given value of armature current are done.

\section*{TO FIND ARMATURE RESISTANCE (Ra):}
1) Connect the circuit per the circuit diagram
2) Keep the rheostat in maximum position.
3) Now excite the motor terminals by 30V supply by closing DPST switch.
4) Note down the readings of Ammeter and voltmeter.

ARMATURE RESISTANCE (Ra):
\begin{tabular}{|c|c|c|c|}
\hline Sl. no & V & I & Ra \\
\hline & & & \\
\hline
\end{tabular}

\section*{CALCULATION TABLE:}

As a Motor:
\begin{tabular}{|l|c|c|c|c|c|}
\hline Sl.No. & \begin{tabular}{c}
\(\mathrm{I}_{\mathrm{L}}\) \\
(A)
\end{tabular} & \begin{tabular}{c}
\(\mathrm{I}_{\mathrm{a}}=\left(\mathrm{I}_{\mathrm{L}}-\mathrm{I}_{\text {sh }}\right)\) \\
\((\mathrm{A})\)
\end{tabular} & \begin{tabular}{c}
\(\mathrm{W}=\mathrm{I}_{\mathrm{a}}{ }^{2} \mathrm{R}_{\mathrm{a}}\) \\
(Watts)
\end{tabular} & TotalLoss & \%Efficiency \\
\hline & & & & & \\
\hline
\end{tabular}

Generator:
\begin{tabular}{|c|c|c|c|c|c|}
\hline Sl.No. & \begin{tabular}{c}
\(\mathrm{I}_{\mathrm{L}}\) \\
(A)
\end{tabular} & \begin{tabular}{c}
\(\mathrm{I}_{\mathrm{a}}=\left(\mathrm{I}_{\mathrm{L}}+\mathrm{I}_{\text {sh }}\right)\) \\
(A)
\end{tabular} & \begin{tabular}{c}
\(\mathrm{W}=\mathrm{I}_{\mathrm{a}}{ }^{2} \mathrm{R}_{\mathrm{a}}\) \\
(Watts)
\end{tabular} & TotalLoss & \%Efficiency \\
\hline & & & & & \\
& & & & \begin{tabular}{l} 
Signature Not Verified \\
Principal.VyEC
\end{tabular} \\
\hline
\end{tabular}

\section*{SAMPLE CALCULATIONS:}

Constant losses \((\mathrm{Wc})=\) No load input - No load armature copper loss
\[
=\mathrm{VI}_{\mathrm{LO}}-\mathrm{I}^{2}{ }_{\mathrm{ao}} \mathrm{Ra} \text {, where } \mathrm{Ra} \text { is the armature resistance }
\]

And \(\mathrm{I}_{\mathrm{ao}}=\mathrm{I}_{\mathrm{L}}-\mathrm{I}_{\mathrm{sh}}\)

\section*{For motor:}
\[
\begin{array}{ll}
\mathrm{I}_{\mathrm{L}}=\mathrm{I}_{\mathrm{a}}+\mathrm{I}_{\mathrm{sh}} & = \\
\text { Input }=\mathrm{VI}_{\mathrm{L}} & = \\
& \\
\text { Cu losses }=\mathrm{Ia}^{2} \mathrm{Ra} & =
\end{array}
\]

Total losses =No load losses or constant losses(Wc)+ cu losses =
\%Efficiency \((\eta)=(\) Output/Input \() * 100=\)

Output \(=\) input-total losses \(=\)

Eg: For full load KW:
\(\mathrm{V}\left(\mathrm{I}_{\mathrm{a}}+\mathrm{I}_{\text {sh }}\right)=\mathrm{KW}+\mathrm{Ia}^{2} \mathrm{Ra}+\mathrm{Wc}=\)

Cu losses \(=\mathrm{Ia}^{2} \mathrm{Ra}=\)
\%Efficiency ( \(\eta\) ) \(=(\text { input-total losses } / \text { Input })^{*} 100=\)
\[
\begin{aligned}
& \text { For generator: } \\
& \mathrm{Ia}=\mathrm{I}_{\mathrm{L}}+\mathrm{I}_{\text {sh }} \\
& \text { Input }=\mathrm{VI}_{\mathrm{L}} \\
& \mathrm{Cu} \text { losses }=\mathrm{Ia}^{2} \mathrm{Ra}=
\end{aligned}
\]

Total losses \(=\) No load losses or contant losses \((\mathrm{Wc})+\mathrm{cu}\) losses \(=\)
\%Efficiency \((\eta)=(\text { Output } / \text { Input })^{*} 100=\)

Input=Output + Losses

\section*{RESULT}

Swinburne's test is performed and efficiency of motor and generator is determined.

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & & & & \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}


\section*{MACHINE DETAILS:}

\section*{HOPKINSON'S TEST ON A PAIR OF DC MACHINES}

\section*{AIM}

To conduct Hopkinson's test on a pair of identical DC machines to pre-determine the efficiency of the machine as generator and as motor under various load conditions.

\section*{OBJECTIVES:}

Determination of the efficiency of the given dc shunts machine working as a motor and generator under various load conditions.

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|c|c|c|}
\hline Sl. No. & Equipments & Specification & Quantity \\
\hline 1 & Ammeter & \((0-1) \mathrm{A}, \mathrm{MC}\) & 1 \\
\hline 2 & Ammeter & \((0-10) \mathrm{A}, \mathrm{MC}\) & 2 \\
\hline 3 & Voltmeter & \(0-300 \mathrm{~V}, \mathrm{MC}\) & 1 \\
\hline 4 & Voltmeter & \(0-600 \mathrm{~V}, \mathrm{MC}\) & 1 \\
\hline 5 & Rheostats & \(400 \Omega, 1.1 \mathrm{~A}\) & 1 \\
\hline & Rheostats & \(800 \Omega, 0.8 \mathrm{~A}\) & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

In Hopiknson's test or regenerative test two identical DC shunt machines are coupled both mechanically and are tested simultaneously. One of the machines is made to run as a motor and it drives other as a generator. For that the field current should be adjusted thus the output of generating machine is fed to the motor. Consequently the power drawn from the supply is used to meet the losses in both the machines. The magnitude of \(\mathrm{I}_{\mathrm{a}}\) can be adjusted to any load condition by varying the If. In this the rotational losses for each machine are considered to the same. Thus we can determine the stray loss and efficiency being determined under load condition. This test can be used for large size machine because the power drawn from the supply is very small.

\section*{MODEL GRAPH:}


TABULAR COLUMN:


\section*{PROCEDURE:}
1. Connections are made as per the circuit diagram.
2. After checking the minimum position of field rheostat of motor, maximum position of field rheostat of generator, opening of SPST switch, DPST switch is closed and starting resistance is gradually removed.
3. The motor is brought to its rated speed by adjusting the field rheostat of the motor.
4. The voltmeter \(\mathrm{V}_{1}\) is made to read zero by adjusting field rheostat of generator and SPST switch is closed.
5. By adjusting field rheostats of motor and generator, various ammeter readings, voltmeter readings are noted.
6. Adjust the rheostat to bring down the load current to be minimum and stop the machine .

\section*{AS MOTOR:}
\begin{tabular}{|l|l|l|l|l|l|l|l|}
\hline \begin{tabular}{c}
\(\mathrm{I}_{\text {LM }}\) \\
(A)
\end{tabular} & \begin{tabular}{c} 
Armature \\
Cu loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Field Loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Stray \\
loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Total \\
losses \\
\(\mathbf{W}_{\mathbf{t}}\) \\
(Wats)
\end{tabular} & \begin{tabular}{c} 
o/p power \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
i/p power \\
(Watts)
\end{tabular} & \(\% \eta\) \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline
\end{tabular}

\section*{AS GENERATOR:}
\begin{tabular}{|l|c|c|c|c|c|c|c|}
\hline \begin{tabular}{c} 
LLM \\
(A)
\end{tabular} & \begin{tabular}{c} 
Armature \\
Cu loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Field \\
Loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Stray \\
loss \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Total \\
losses \\
\(\mathbf{W}_{\mathbf{t}}\) \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
o/p \\
power \\
(Watts)
\end{tabular} & \begin{tabular}{c}
\(\mathrm{i} / \mathrm{p}\) power \\
(Watts)
\end{tabular} & \(\% \eta\) \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & & \\
\hline & & & & & & \\
\hline
\end{tabular}

\section*{FORMULAE USED:}

Input Power

Motor armature cu loss
\[
=\mathrm{VI}_{1} \text { watts }
\]
\[
\left.=\left(\mathrm{I}_{1}-\mathrm{I}_{3}\right)+\mathrm{I}_{2}\right)^{2} \text { Ra watts }
\]

Generator armature cu loss \(\quad=\left(\mathrm{I}_{2}+\mathrm{I}_{4}\right)^{2} \mathrm{R}_{\mathrm{A}}\)
Total Stray losses W
\(=\quad \mathrm{VI}_{1}-\left(\mathrm{I}_{2}+\mathrm{I}_{4}\right)^{2} \mathrm{R}_{\mathrm{A}}-\left(\mathrm{I}_{1}+\mathrm{I}_{2}-\mathrm{I}_{3}\right)^{2} \mathrm{R}_{\mathrm{A}}-\mathrm{V}\left(\mathrm{I}_{3}+\mathrm{I}_{4}\right)\)

Stray loss per machine
\(=\mathrm{W} / 2\) watts.

\section*{AS MOTOR:}

Input Power

Total Losses

Efficiency \(\eta \%\)

\section*{AS GENERATOR:}

Output Power
Total Losses

Efficiency \(\eta \%\)
\[
\begin{aligned}
& =\text { Armature input }+ \text { Shunt field input } \\
& =\left(\mathrm{I}_{1}+\mathrm{I}_{2}\right) \mathrm{V}=\left(\mathrm{I}_{1}+\mathrm{I}_{2}\right) \mathrm{V} \\
& =\text { Armature } \mathrm{Cu} \text { loss }+ \text { Field loss }+ \text { stray loss } \\
& \left(\mathrm{I}_{1}-\mathrm{I}_{3}+\mathrm{I}_{2}\right)^{2} \mathrm{Ra}+\mathrm{VI}_{3}+\mathrm{W} / 2 \text { watts } \\
& \text { Input power - Total Losses } \\
& = \\
& \text { x } 100 \%
\end{aligned}
\]

Input Power
\[
\begin{aligned}
& =\mathrm{VI}_{2} \text { watts } \\
& =\text { Armature } \mathrm{Cu} \text { loss }+ \text { Field Loss }+ \text { Stray loss } \\
& =\left(\mathrm{I}_{2}+\mathrm{I}_{4}\right)^{2} \mathrm{Ra}+\mathrm{VI}_{4}+\mathrm{W} / 2 \text { watts } \\
& \text { Output power } \\
& \text { = ------------------------------------- x } 100 \% \\
& \text { Output Power+ Total Losses }
\end{aligned}
\]

\section*{SAMPLE CALCULATION}

\section*{RESULT}

Thus Hopkinson's test is conducted on a pair of identical DC machines the efficiency of the machine as generator and as motor are pre-determined.

\section*{ASSESSMENT RUBRICS}


\section*{CIRCUIT DIAGRAM}


\section*{MACHINE DETAILS}

\section*{EXPECTED GRAPH:}

f

\section*{SEPARATION OF LOSSES IN A DC SHUNT MACHINE}

\section*{AIM}

To separate the stray losses in a dc machine by conducting no load test at different excitation and to plot the variation of these losses at different speeds.

\section*{OBJECTIVES:}
a) Separation of hysteresis, eddy current, friction \& windage losses
b) Plot the losses vs speed curves

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|l|l|l|}
\hline \begin{tabular}{c} 
Sl. \\
No.
\end{tabular} & \multicolumn{1}{|c|}{ Equipments } & Specification & \multicolumn{1}{|c|}{ Quantity } \\
\hline 1 & Ammeter & \((0-5) \mathrm{A}, \mathrm{MC}\) & 1 \\
\hline 2 & Ammeter & \((0-1) \mathrm{A}, \mathrm{MC}\) & 1 \\
\hline 3 & Voltmeter & \((0-300) \mathrm{V}, \mathrm{MC}\) & 1 \\
\hline 4 & Rheostat & \(570 \Omega, 1.2 \mathrm{~A}\) & 2 \\
\hline 5 & Tachometer & & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

The stray losses of a dc machine consist of the following components:-
For normal excitation:-
a) Brush friction loss, \(=\mathrm{AN}\)
b) Bearing friction and windage loss \(=\mathrm{BN}^{2}\)
c) Hysteresis loss, \(W_{h} \quad=\mathrm{CN}\)
d) Eddy current, \(W_{e}\)
\(=D N^{2}\)
Therefore stray loss, \(\longrightarrow W_{s}=A N+B N^{2}+C N+D N^{2}\)
\[
\longrightarrow \quad W_{s}=(A+C) N+(B+D) N^{2}
\]
\[
\longrightarrow \quad \frac{W_{\varepsilon}}{N}=(A+C)
\]

For reduced excitation:-
a) Brush friction loss,
\(=\mathrm{AN}\)
b) Bearing friction and windage loss \(=\mathrm{BN}^{2}\)
c) Hysteresis loss, \(W_{h}{ }^{\prime}\)
\(=C^{\prime} \mathrm{N}\)
Signature Not Verified
d) Eddy current, \(W_{e}\) '
\(=D^{\prime} N^{2}\)

\section*{TABULAR COLOUMN}
\begin{tabular}{|c|c|c|c|c|c|c||}
\hline & Sl. no & \begin{tabular}{c} 
Armature \\
voltage V
\end{tabular} & \begin{tabular}{c} 
No load \\
current Ia \\
(A)
\end{tabular} & \begin{tabular}{c} 
Speed N \\
(rpm)
\end{tabular} & \begin{tabular}{c} 
Stray loss \\
Ws (Watts)
\end{tabular} & W?/? \\
\hline \begin{tabular}{c} 
Normal \\
excitation
\end{tabular} & \(\mathbf{1}\) & & & & & \\
\cline { 2 - 7 } & 2 & & & & & \\
\cline { 2 - 7 } & 3 & & & & & \\
\hline & 4 & & & & \\
\hline \multirow{5}{*}{\begin{tabular}{c} 
Reduced \\
excitation
\end{tabular}} & \(\mathbf{1}\) & & & & \\
\cline { 2 - 7 } & 2 & & & & & \\
\hline
\end{tabular}

Where, \(W_{s}=V I_{a}-I_{a}{ }^{2} R_{a}\)

\section*{SAMPLE CALCULATION}

For normal excitation with speed \(N_{1}\),
Stray loss \(=W_{s}=(A+C) N+(B+D) N^{2}\)

Where Y intercept, OP \(\longrightarrow(\mathrm{A}+\mathrm{C})\) from the graph \(\frac{W_{s}}{N} \mathrm{Vs} \mathrm{N}\)

Slope of \(\frac{W_{s}}{N}\) Vs N (Normal excitation) \(\longrightarrow(\mathrm{B}+\mathrm{D})\)

For reduced excitation (for same speed as above)
Stray loss, \(W_{s}^{\prime}=\left(A+C^{\prime}\right) N+\left(B^{\prime}+D^{\prime}\right) N^{2}\)

\section*{PROCEDURE}

Connections are done as shown in the figure. The shunt field resistance \(\mathrm{Rh}_{1}\) is kept at minimum position and armature resistance \(\mathrm{Rh}_{2}\) is kept at minimum position. Supply isswitched ON and DC machine (motor) is started using 3 point starter. By adjusting field excitation rheostat, \(\mathrm{Rh}_{1}\) field excitation and speed is brought to rated (normal) value. Keeping excitation constant ie:without disturbing \(\mathrm{Rh}_{1}, \mathrm{Rh}_{2}\) is adjusted for different speeds. Note down all readings. Now by adjusting the rheostat \(R h_{1}\), bring the excitation to reduced value ( \(60 \%\) normal value). Keeping excitation constant rheostat, ie:- without disturbing \(\mathrm{Rh}_{1}, \mathrm{Rh}_{2}\) is adjusted for different speeds. Note down all readings. Note:-take at least one reading common to both the excitations.

Y intercepts, \(\mathrm{OQ} \longrightarrow\left(A+C^{\prime}\right)\) from the graph \(\frac{W_{s^{\prime}}}{N}\) Vs N

Slope of \(\frac{W_{s^{\prime}}^{\prime}}{N}\) Vs N (Reduced excitation) \(\longrightarrow\left(\mathrm{B}+D^{\prime}\right)\)

Therefore stray loss, \(\longrightarrow W_{s}^{\prime}=A N+B N^{2}+C^{\prime} N+D^{\prime} N^{2}\)
\(\longrightarrow \quad W_{s}^{\prime}=\left(A+C^{\prime}\right) N+\left(B^{\prime}+D^{\prime}\right) N^{2}\)
\(\longrightarrow \quad \frac{W_{s}^{\prime}}{N}=\left(A+C^{\prime}\right)+\left(B^{\prime}+D^{\prime}\right) N\)
Where \(\mathrm{A}, \mathrm{B}, \mathrm{C}, \mathrm{D}, C^{\prime}, D^{\prime}\) are all constants.

The graph \(\frac{W_{s}}{N}\) Vs N and \(\frac{W_{s^{\prime}}}{N}\) Vs N are plotted. Both the graphs result in straight lines.
From these graphs,
Y intercept, \(\mathrm{OP} \longrightarrow(\mathrm{A}+\mathrm{C})\) from the graph \(\frac{W_{s}}{N} \mathrm{Vs} \mathrm{N}\)
Y intercept, \(\mathrm{OQ} \longrightarrow\left(\mathrm{A}+C^{\prime}\right)\) from the graph \(\frac{W_{s}^{\prime}}{N}\) Vs N
Slope of \(\frac{W_{s}}{N} \mathrm{VsN}\) (Normal excitation) \(\longrightarrow(\mathrm{B}+\mathrm{D})\)
Slope of \(\frac{W_{s}^{\prime}}{N}\) Vs N (Reduced excitation) \(\longrightarrow\left(\mathrm{B}+D^{\prime}\right)\)

For the same speed N1 both for normal and reduced excitation,
\(\frac{W_{h}}{W_{h^{\prime}}}=\frac{C N}{C^{\prime} N}=\frac{C}{C^{\prime}}=\frac{B_{\max }{ }^{1.6}}{B_{\max }^{1.6}}=\frac{E_{b 1}{ }^{1.6}}{E_{b 2}^{1.6}}=\frac{\left(V-I_{a} R_{a}\right)^{1.6}}{\left(V^{\prime}-I_{a} R_{a}\right)^{1.6}}\)
\(\frac{W_{e}}{W_{e}^{\prime}}=\frac{D N^{2}}{D^{\prime} N^{2}}=\frac{D}{D^{\prime}}=\frac{\left(V-I_{a} R_{a}\right)^{2}}{\left(V^{\prime}-I_{a} R_{a}\right)^{2}}\)

Find \(\frac{C}{C}\) for the same speed N1
\(\frac{C}{C^{\prime}}=\frac{\left(V-I_{a} R_{a}\right)^{1.6}}{\left(V^{\cdot}-I_{a}{ }^{\prime} R_{a}\right)^{1.6}}\)

And similarly,
\(\frac{D}{D^{\prime}}=\frac{\left(V-I_{a} R_{a}\right)^{2}}{\left(V^{\prime}-I_{a}^{\prime} R_{a}\right)^{2}}\)
Solve the equations and find \(\mathrm{A}, \mathrm{B}, \mathrm{C}, \mathrm{D}, C^{\prime}, D\)

Therefore,
For any speed N1,
Brush friction loss, \(\quad=\) AN1
Bearing friction and windage loss \(\quad=B N 1^{2}\)
Hysteresis loss, \(W_{h}{ }^{\prime} \quad=C^{\prime} \mathrm{N}\)
Eddy current, \(W_{e}{ }^{\prime} \quad=D^{\prime} N^{2}\)

\section*{RESULT}

Separated the stray losses in a dc machine by conducting no load test at different excitation and plotted the variation of these losses at different speeds.

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline \begin{tabular}{c} 
Preliminary \\
Work
\end{tabular} & \begin{tabular}{c} 
Implementing the \\
Work/Conducting \\
the Experiment
\end{tabular} & \begin{tabular}{c} 
Calculations, \\
Result and \\
Inference
\end{tabular} & Viva voce & \begin{tabular}{c} 
Record \\
Submission
\end{tabular} \\
\hline \(\mathbf{5}\) & \(\mathbf{5}\) & \(\mathbf{5}\) & \(\mathbf{1 0}\) & \(\mathbf{5}\) \\
\hline \begin{tabular}{c} 
Total Marks \\
scored \\
\(\&\)
\end{tabular} & & \\
\begin{tabular}{c} 
Signature of \\
Faculty
\end{tabular} & & Signature Not Verified \\
\hline
\end{tabular}

Total stray loss \(\quad=\mathrm{AN} 1+\mathrm{BN} 1^{2}+C^{\prime} \mathrm{N}+D^{\cdot} N^{2}\)
\begin{tabular}{|c|c|c|c|c|c|}
\hline \begin{tabular}{c} 
Excitation, \\
If \\
(A)
\end{tabular} & \begin{tabular}{c} 
Speed \\
(rpm) \\
N1
\end{tabular} & \begin{tabular}{c} 
Brush \\
friction loss, \\
AN1 \\
(Watts)
\end{tabular} & \begin{tabular}{c} 
Bearing \\
friction loss, \\
BN1 \\
(watts)
\end{tabular} & \begin{tabular}{c} 
Hysteresis \\
loss \\
\(C^{\prime}\) ' \\
(watts)
\end{tabular} & \begin{tabular}{c} 
Eddy \\
current loss \\
\(D^{\prime} \boldsymbol{N}^{\mathbf{2}}\) \\
(watts)
\end{tabular} \\
\hline Normal & & & & & \\
\hline Reduced & & & & & \\
\hline
\end{tabular}

VIVA

\section*{CIRCUIT DIAGRAM}

OC TEST:


\section*{SC TEST:}


\section*{O.C TEST OBSERVATIONS:}
\begin{tabular}{|l|l|l|l|}
\hline S.NO & \(\mathrm{V}_{0}\) (VOLTS) & \(\mathbf{I}_{0}\) (AMPS) & \(\mathbf{W}_{0}\) (WATTS) \\
\hline & & & \\
& & & \\
\hline
\end{tabular}

\section*{S.C TEST OBSERVATIONS:}
\begin{tabular}{|c|c|c|c|}
\hline S.NO & \(\mathbf{V}_{\mathrm{SC}}(\) VOLTS & \(\mathbf{I}_{\mathrm{SC}}\) (AMPS) & \(\mathbf{W}_{\mathrm{SC}}\) (WATTS) \\
\hline & & & Signature Not Verified \(^{2}\) \\
& & & Principail.VJEC \\
\hline
\end{tabular}
\(\qquad\)

\section*{OC\&SC TESTS ON SINGLE-PHASE TRANSFORMER}

\section*{AIM}

To conduct Open circuit and Short circuit tests on 1-phase transformer to predetermine the efficiency, regulation and equivalent parameters.

\section*{OB,JECTIVES:}

To predetermine
a) To pre-determine the regulation and efficiency of the given single phase transformer a different loads and power factors
b) To obtain the equivalent circuit of the given transformer
c) To plot regulation vs power factor curves
d) To determine the power factors at which regulation is zero

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|l|l|l|}
\hline \begin{tabular}{c} 
Sl. \\
No.
\end{tabular} & \multicolumn{1}{|c|}{ Equipments } & Specification** & Quantity \\
\hline 1 & Ammeter & & \\
\hline 2 & Ammeter & & \\
\hline 3 & Voltmeter & & \\
\hline 4 & Voltmeter & & \\
\hline 5 & Wattmeter & & \\
\hline 6 & Wattmeter & & \\
\hline
\end{tabular}
**Specifications of meters used
Note down the transformer's nameplate details (KVA, Primary \& secondary rated voltages, Primary \& secondary rated currents.)
Auto transformer - \(0-120 \%\) output voltage
Ammeter (A1) - as per the no load current of LV side (no load current of a transformer is 2 to \(6 \%\) of the full load current)
Ammeter (A2) - as per the full load current of HV side
Voltmeter (V1) - as per the LV rated voltage
Voltmeter (V2) - 5 to \(10 \%\) of the HV side voltage (The voltage required for circulating the rated current, if the other side is short circuited is 5 to \(10 \%\) of rated voltage.)
Wattmeter (W1) - current range as same as A1, voltage range as same as V1, LPF (no load pf of transformer is below 0.5)
Wattmeter (W2) - current range as same as A2, voltage range as same as V2, UPF

\section*{PRINCIPLE}

Transformer is a device which transforms the energy from one circuit to other cißcigitatuite Notchearitijed of frequency. The performance of any transformer can be determined by conducting tests. Ob DC and SC tests are conducted on transformer to find losses occurring in transformer and henc helpe it predetermine the efficiency and regulation of the transformer at any desired load curleftipal.VJEC

\section*{SAMPLE CALCULATIONS}

\section*{From OC test}

The no-load power \(\mathrm{W}_{\mathrm{o}}=\mathrm{V}_{\mathrm{o}} \times \mathrm{I}_{\mathrm{o}} \times \cos \emptyset_{\mathrm{o}}\)
where \(\mathrm{V}_{\mathrm{o}}\) is the rated [no-load] voltage
\(I_{o}\) is the no-load current, and \(\emptyset_{o}\) is the phase angle between \(V_{o}\) and \(I_{o}\)
Therefore, \(\cos \emptyset_{0}=W_{o} /\left[\mathrm{V}_{0} \times \mathrm{I}_{\mathrm{o}}\right]=\)
\[
\begin{array}{ll}
\mathrm{I}_{\mathrm{w}}=\mathrm{I}_{0} \times \cos \emptyset_{o} & = \\
\mathrm{I}_{\mu}=\mathrm{I}_{0} \times \sin \emptyset_{o} & =
\end{array}
\]

In the equivalent circuit diagram, the loss component \(I_{w}\) is represented by \(R_{o}\) and magnetizing component \(I_{\mu}\) is represented by \(\mathrm{X}_{\mathrm{o}}\)
\[
\begin{array}{lll}
\mathrm{R}_{\mathrm{o}}=\mathrm{V}_{\mathrm{o}} / \mathrm{I}_{\mathrm{w}} & = & \quad \text { (referred to L V side) } \\
\mathrm{X}_{\mathrm{o}}=\mathrm{V}_{\mathrm{o}} / \mathrm{I}_{\mu} & = &
\end{array}
\]

\section*{From S.C Test}

Wattmeter Reading, \(\boldsymbol{W}_{S C}=\boldsymbol{I}_{S C}^{2} \times \boldsymbol{R}_{\mathrm{O} 2}\)
[where Isc is the short cicuit current [ full load current] and \(\mathrm{R}_{02}\) is equivalent resistance of transformer referred to HV side]

Therefore, equivalent resistance, \(\boldsymbol{R}_{02}=\frac{W_{S C}}{I_{S C}^{2}}=\)
Equivalent impedence referred to HV side, \(Z_{02}=\frac{V_{S C}}{I_{S C}}=\)
[where Vsc is the voltage applied under short circuit condition to circulate the short cicuit current \(\mathrm{I}_{\mathrm{sc}}\) ]
Therefore, equivalent reactance, \(X_{02}=\sqrt{Z_{02}^{2}-R_{02}^{2}}\)
\(\mathrm{R}_{02}\) and \(\mathrm{X}_{02}\) are referred to HV side.To trasfer these values to LV side,
\(\mathrm{R}_{01}=\mathrm{R}_{02}\left(\mathrm{~N}_{1} / \mathrm{N}_{2}\right)^{2}\)
\(\mathrm{X}_{01}=\mathrm{X}_{02}\left(\mathrm{~N}_{1} / \mathrm{N}_{2}\right)^{2}\)
Where, \(\mathrm{N} 1 / \mathrm{N} 2\) = no of HV side turns/no of LV side turns that is(LV side voltage/ HV side voltage)
\(\mathrm{R}_{0}{ }^{\prime}=\mathrm{R}_{0} \times\left(\mathrm{N}_{2} / \mathrm{N}_{1}\right)^{2}=\)
And \(\mathrm{X}_{0}{ }^{\prime}=\mathrm{X}_{0} \times\left(\mathrm{N}_{2} / \mathrm{N}_{1}\right)^{2}=\)

\section*{OC TEST:}

The objectives of OC test are
1. To find out the constant losses or iron losses of the transformer.
2. To find out the no load equivalent parameters.

\section*{SC TEST:}

The objectives of SC test are
1. To find out the variable losses or copper losses of the transformer.
2. To find out the short circuit equivalent parameters.

By calculating the losses and equivalent parameters from the above tests the efficiency and regulation can be calculated at any desired power factor.

\section*{PROCEDURE (OC TEST):}
1. Connections are made as per the circuit diagram.
2. Initially variac should be kept in its minimum position.
3. Close the DPST switch.
4. By varying Auto transformer bring the voltage to rated voltage.
5. When the voltage in the voltmeter is equal to the rated voltage of HV winding note down all the readings of the meters.
6. After taking all the readings bring the variac to its minimum position.
7. Now switch off the supply by opening the DPST switch.

\section*{PROCEDURE (SC TEST):}
1. Connections are made as per the circuit diagram.
2. Short the LV side and connect the meters on HV side.
3. Before taking the single phase, \(230 \mathrm{~V}, 50 \mathrm{~Hz}\) supply the variac should be in minimum position.
4. Now close the DPST switch so that the supply is given to the transformer.
5. By varying the variac when the ammeter shows the rated current then note down all the readings.
6. Bring the variac to minimum position after taking the readings and switch off the supply.

\section*{EQUIVALENT CIRCUIT REFERRED TO LV SIDE:}


EQUIVALENT CIRCUIT REFERRED TO HV SIDE:


Load fraction \(\mathrm{x}=\)
\(\operatorname{Pf} \operatorname{Cos} \Phi=\)
\(\operatorname{Sin} \phi=\)
Total losses \(=w_{0}+x^{2}{ }_{*} \mathrm{~W}_{\mathrm{sc}}\)
\(\mathrm{O} / \mathrm{P}\) at full load and at \(\mathrm{UPF}=\) rated \(\mathrm{KVA} * 1000=\)
\(\mathrm{O} / \mathrm{P}\) at x times full load and at \(\cos \Phi=\mathrm{x} *\) rated KVA * \(1000 * \mathrm{pf}=\)
\(\mathrm{i} / \mathrm{p}=\mathrm{o} / \mathrm{p}+\) losses \(=\)

Efficiency \(=\) output/ input * \(100=\)

Regulation for Lagging \(\operatorname{Pf}=\frac{x l_{2}}{V}\left(R_{02 \operatorname{Cos} \Phi^{+}} X_{02 \operatorname{Sin} \phi}\right) * 100 \%=\)

Regulation For Leading \(\operatorname{Pf}=\frac{x l_{2}}{V}\left(R_{02} \operatorname{Cos} \Phi X_{02 \operatorname{Sin} \Phi}\right) * 100 \%=\)

\section*{SAMPLE CALCULATION UPF LOAD AT MAXIMUM EFFICIENCY}

For maximum efficiency, copper loss \(=\) iron loss
Let max efficiency occurs at x times full load, then
\(w_{0}=x^{2} * W_{\mathrm{sc}}\)
\(\mathrm{x}=\sqrt{\frac{w_{0}}{w_{s c}}}=\)

\section*{CALCULATION FOR MAXIMUM REGULATION AND ZERO REGULATION}

For maximum regulation, \(\tan \Phi=\frac{X_{02}}{R_{02}}=\)
\(\operatorname{Cos} \phi=\)

For zero regulation, \(\tan \phi=\frac{R_{02}}{X_{02}}=\)
\(\operatorname{Cos} \Phi=\)

\section*{TABULAR COLUMN}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline \multirow[t]{3}{*}{S} & \multirow[t]{3}{*}{\begin{tabular}{l}
Load \\
Fract \\
ion \\
X
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
PF \\
Co \\
s \(\Phi\)
\end{tabular}} & \multirow[t]{3}{*}{Sin \(\Phi\)} & \multirow[t]{3}{*}{\begin{tabular}{l}
Iron \\
loss, \\
\(W_{0}(w)\)
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
Cu loss,
\[
x^{2} * \mathrm{~W}
\] \\
sc \\
(w)
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
Total \\
losses
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
Output=X \\
*rated \\
KVA* 10 \\
\(00 * \operatorname{Cos} \Phi\) \\
in watts
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
\(\mathrm{i} / \mathrm{p}=\) out \\
put \\
+total \\
losses \\
in watts
\end{tabular}} & \multirow[t]{3}{*}{\begin{tabular}{l}
effici \\
ency \\
\%
\end{tabular}} & \multicolumn{2}{|l|}{\multirow[t]{2}{*}{\begin{tabular}{l}
Regulation \\
\%
\end{tabular}}} \\
\hline & & & & & & & & & & & \\
\hline & & & & & & & & & & lag & lead \\
\hline 1 & 0.25 & 1.0 & . 0000 & & & & & & & & \\
\hline 2 & & 0.8 & . 6000 & & & & & & & & \\
\hline 3 & & 0.6 & . 8000 & & & & & & & & \\
\hline 4 & & 0.4 & . 9165 & & & & & & & & \\
\hline 5 & & 0.2 & . 9798 & & & & & & & & \\
\hline 1 & 0.50 & 1.0 & . 0000 & & & & & & & & \\
\hline 2 & & 0.8 & . 6000 & & & & & & & & \\
\hline 3 & & 0.6 & . 8000 & & & & & & & & \\
\hline 4 & & 0.4 & . 9165 & & & & & & & & \\
\hline 5 & & 0.2 & . 9798 & & & & & & & & \\
\hline 1 & 0.75 & 1.0 & . 0000 & & & & & & & & \\
\hline 2 & & 0.8 & . 6000 & & & & & & & & \\
\hline 3 & & 0.6 & . 8000 & & & & & & & & \\
\hline 4 & & 0.4 & . 9165 & & & & & & & & \\
\hline 5 & & 0.2 & . 9798 & & & & & & & & \\
\hline 1 & 1.00 & 1.0 & . 0000 & & & & & & & & \\
\hline 2 & & 0.8 & . 6000 & & & & & & & & \\
\hline 3 & & 0.6 & . 8000 & & & & & & & & \\
\hline 4 & & 0.4 & . 9165 & & & & & & & & \\
\hline 5 & & 0.2 & . 9798 & & & & & & & & \\
\hline 1 & 1.25 & 1.0 & . 0000 & & & & & & & & \\
\hline 2 & & 0.8 & . 6000 & & & & & & & & \\
\hline 3 & & 0.6 & . 8000 & & & & & & & & \\
\hline 4 & & 0.4 & . 9165 & & & & & & & & \\
\hline 5 & & 0.2 & . 9798 & & & & & & & & \\
\hline & & & & & & & & & & & \\
\hline
\end{tabular}

\section*{RESULT}

Conducted OC and SC test on the given single phase transformer and the following results are obtained
a) Pre-determined the regulation and efficiency of the given single phase transformer at different loads and power factors
b) Obtained the equivalent circuit of the given transformer
c) Plotted regulation vs power factor curves
d) Determined the power factors at which regulation is zero

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & \multicolumn{4}{|l|}{} \\
\hline
\end{tabular}

\section*{SAMPLE GRAPHS:}
1. EFFICIENCY VS OUTPUT

output power in watts

\section*{2. EFFICIENCY VS POWER FACTOR}


VIVA

\section*{CIRCUIT DIAGRAM:}


FUSERATING:
\(125 \%\) of rated current
\[
\frac{125 \times 5}{100}=6.25 A
\]

NAME PLATEDETAILS:
\begin{tabular}{lcc} 
& Primary & Secondary \\
Rated Voltage : & 230 V & 115 V \\
Rated Cument : & 5 A & 10 A \\
Rated Power : & 1 KVA & 1 KVA
\end{tabular}

\section*{SAMPLE GRAPH:}

\(\qquad\)

\section*{DIRECT LOAD TEST ON SINGLE PHASE TRANSFORMER}

\section*{AIM}

To conduct, load test on a single phase transformer.

\section*{OB,JECTIVES:}
1. Determination of efficiency at different load conditions and upf.
2. Determination of regulation at different load conditions and upf.
3. Plot efficiency vs. output and regulation vs. output curves.

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|l|l|l|}
\hline NO. & \multicolumn{1}{|c|}{ EQUIPMENTS } & SPECIFICATION & \multicolumn{1}{|c|}{ QUANTITY } \\
\hline 1 & Ammeter & \((0-5 \mathrm{~A}), \mathrm{MI}\) & 1 \\
\hline 2 & Ammeter & \((0-10 \mathrm{~A}) \mathrm{MI}\) & 1 \\
\hline 3 & Voltmeter & \((0-300 \mathrm{~V}), \mathrm{MI}\) & 1 \\
\hline 4 & Voltmeter & \((0-150 \mathrm{~V}), \mathrm{MI}\) & 1 \\
\hline 5 & Wattmeter & \(5 \mathrm{~A}, 300 \mathrm{~V}, \mathrm{UPF}\) & 1 \\
\hline 6 & Wattmeter & \(5 \mathrm{~A}, 150 \mathrm{~V}, \mathrm{UPF}\) & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

In this test the efficiencies and regulation are determined by direct loading of the given single phase transformer this test is very often carried out in practice excepting for small sizes, owing to the difficulty of obtaining a suitable load and the loss of power involved. Whenevera transformer is loaded its secondary terminal voltage changes with increased load, if the supplied primary voltage is held constant, the change in secondary voltage from no load to full load expressed as percentage of no load voltage is known as voltage regulation of a transformer. The efficiency of a transformer is defined as the ratio of output power to input power, efficiency =output power/input power* 100. In this experiment input power is measured directly from the wattmeter connected in the primary side and output power is obtained by gigndaiple Not therifiedt meter reading and ammeter reading in the secondary side or directly from the attmeter connected in the secondary side.

\section*{TABULAR COLOUMN}
\begin{tabular}{|l|l|l|l|l|l|l|l|l|l|}
\hline \begin{tabular}{l} 
Sl. \\
No
\end{tabular} & \multicolumn{3}{|l|}{ Primary readings } & \multicolumn{3}{l|}{ Secondary readings } & \multicolumn{1}{l}{\begin{tabular}{l} 
Efficiency \\
in \%
\end{tabular}} \\
\cline { 2 - 8 } & \(\mathrm{W}_{1}\) & \(\mathrm{~V}_{1}\) & \begin{tabular}{l}
I \\
1
\end{tabular} & \(\mathrm{~W}_{2}\) & \(\mathrm{~V}_{2}\) & \(\mathrm{I}_{2}\) & \begin{tabular}{l} 
Regulation \\
\(\%\)
\end{tabular} \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline & & & & & & & & \\
\hline
\end{tabular}

\section*{SAMPLE CALCULATIONS:}

VNL= Volt
VL= Volt
\(\mathrm{W}_{1}=\)
\(\mathrm{W}_{2}=\)

Efficiency \(=\left(W_{2} / W_{1}\right)=\)
\% Regulation = (Vnl-VL) / Vnlx \(100=\)

\section*{PROCEDURE}
1. Connect the circuit diagram as per the circuit diagram
2. Adjust the autotransformer till the voltmeter reads rated voltage.
3. Note the no load readings and enter them as first set of readings in tabular column.
4. Load the transformer gradually and take all meter readings each time till the secondary current reaches rated value.
5. Tabulate the readings

\section*{RESULT}

Conducted load test on a single phase transformer and the following objectives are obtained
- Determined efficiency at different load conditions and upf.
- Determined regulation at different load conditions and upf.
- Plotted efficiency vs. output and regulation vs. output curves.

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & & & & \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}


\section*{EXPECTED GRAPH:}

\(\qquad\)

\section*{SEPARATION OF LOSSES IN A 1 \(\Phi\) TRANSFORMER}

\section*{AIM}

To separate the core losses into hysteresis loss and eddy current loss by conducting no load test, keeping V/F constant on a \(1 \phi\) transformer.

\section*{OBJECTIVES:}
1. Separate the hysteresis and eddy current losses at normal voltage and different frequencies and plot losses vs. frequency curves.
2. Separate the hysteresis and eddy current losses at normal frequency and different voltages and plot losses vs. voltage curves.

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|l|l|c|}
\hline No & \multicolumn{1}{|c|}{ Equipments } & Specification & Quantity \\
\hline 1 & Wattmeter & & \\
\hline 2 & Voltmeter & & \\
\hline 3 & Ammeter & & \\
\hline 4 & Rheostat & & \\
\hline
\end{tabular}

\section*{PRINCIPLE}

Hysteresis and eddy current losses are called iron loss and take place in core of the transformer

Hysteresis loss is given by \(=\mathrm{W}_{\mathrm{h}}=\mathrm{KB}_{\max }{ }^{1.6} \mathrm{f}=\mathrm{Af}\)
Eddy current loss also depends on the frequency \(f\) and is given by
\[
\mathrm{We}=\mathrm{KB}^{2}{ }_{\text {max }} \mathrm{f}^{2} \mathrm{t}^{2}=\mathrm{Bf}^{2}
\]
\(\mathrm{B}_{\text {max }}=\) Maximum flux density weber \(/ \mathrm{m}^{2} \mathrm{f}=\) frequency cycles/ seconds
\(t=\) thickness of stamping

\section*{TABULAR COLOUMN}
\begin{tabular}{|l|l|l|c|c|c|c|}
\hline Sl.No & \begin{tabular}{c} 
Frequency \\
(Hz)
\end{tabular} & \begin{tabular}{c} 
Voltage \\
(V)
\end{tabular} & \begin{tabular}{c} 
Speed \\
(rpm) \\
\(\mathrm{N}=120 \mathrm{f} / \mathrm{p}\)
\end{tabular} & \begin{tabular}{c} 
Current \\
I(A)
\end{tabular} & Wi (watts) & Wi /f \\
\hline 1 & 50 & & & & & \\
\hline 2 & 48 & & & & & \\
\hline 3 & 47 & & & & & \\
\hline 4 & 46 & & & & & \\
\hline 5 & 45 & & & & & \\
\hline
\end{tabular}

\section*{SAMPLE CALCULATIONS:}

From graph Wi/f vs. f \(A=\)
\[
\mathrm{B}=
\]

Hysteresis loss at rated frequency and rated voltage, \(\mathrm{Wh}=\mathrm{Af}=\mathrm{A} * 50=\)

Eddy current loss at rated frequency and rated voltage, \(\mathrm{W}_{\mathrm{e}}=\mathrm{B}^{2}=\mathrm{B} * 50^{2}=\)

Iron loss, \(\mathrm{W}_{\mathrm{i}}=\mathrm{W}_{\mathrm{h}}+\mathrm{W}_{\mathrm{e}}\)

The iron loss will be expressed by
\[
\begin{gathered}
W_{i}=\mathrm{Af}+\mathrm{Bf}^{2} \\
W_{i} / \mathrm{f}=\mathrm{A}+\mathrm{Bf}, \quad \mathrm{y}=\mathrm{mx}+\mathrm{c}
\end{gathered}
\]

This is equation of straight line \(\mathrm{y}=\mathrm{mx}+\mathrm{c}\), when \(\mathrm{y}=\mathrm{w}_{\mathrm{i}} / \mathrm{f}, \mathrm{c}=\mathrm{A}\), and \(\mathrm{m}=\mathrm{B}\) and \(\mathrm{x}=\mathrm{f}\).

Eddy current and Hysteresis loss can be separated when A and B are found. The variable frequency supply is obtained from an alternator whose frequency can be varied.

\section*{PROCEDURE}
(1) Connections are done as per the circuit diagram.
(2) Initially rheostat in the armature circuit of motor is kept at maximum position, the rheostat in the field circuit of motor is kept at minimum position and the rheostats in the field circuit (potential divider)of the alternator are kept so that minimum voltage is applied to the field circuit of the alternator.
(3) Start the motor with the help of 3-point starter
(4) Bring the speed of the motor to the rated speed by using the rheostats of the motor.
(5) By increasing the excitation of alternator using the potential divider bring the voltage of the alternator to the rated voltage.
(6) Apply the rated voltage to the high voltage side of the transformer by closing the DPDT switch.
(7) Note down all the meter readings and speed.
(8) Alternator is made to run at different speeds below the rated speed and adjust the voltage of the alternator, so that \(\mathrm{v} / \mathrm{f}\) ratio is constant.
(9) At each and every speed, note down the readings of voltmeter, ammeter, wattmeter and the speed of the motor.
(10) Perform the experiment up to \(80 \%\) of the rated speed and graphs are drawn.

\section*{LOSSES AT NORMAL VOLTAGE AND DIFFERENT FREQUENCIES}
\(\mathrm{W}_{\mathrm{h} 1}=\mathrm{Af}=\mathrm{A} * 50=\)
\(\mathrm{W}_{\mathrm{e} 1}=\mathrm{B} \mathrm{f}^{2}=\mathrm{B} * 50^{2}=\)
\begin{tabular}{|l|l|l|l|l|l|}
\hline FREQUENCY & 50 & 40 & 30 & 25 & 20 \\
\hline \(\mathrm{~W}_{\mathrm{h} 2}=\mathrm{W}_{\mathrm{h} 1} *\left\{\mathrm{f}_{\mathrm{nom}} / \mathrm{f}\right\}^{0.6}\) & & & & & \\
\hline \(\mathrm{~W}_{\mathrm{e} 2}=\mathrm{W}_{\mathrm{e} 1}\) & & & & & \\
& & & & & \\
\hline \(\mathrm{~W}_{\mathrm{i}}=\mathrm{W}_{\mathrm{h}}+\mathrm{W}_{\mathrm{e}}\) & & & & & \\
\hline
\end{tabular}

\section*{LOSSES AT NORMAL FREQUENCY AND DIFFERENT VOLTAGES}
\(\mathrm{W}_{\mathrm{h} 1}=\mathrm{Af}=\mathrm{A} * 50=\)
\(\mathrm{W}_{\mathrm{e} 1}=\mathrm{B} \mathrm{f}^{2}=\mathrm{B} * 50^{2}=\)
\begin{tabular}{|l|l|l|l|l|l|}
\hline VOLTAGE & 115 & 110 & 105 & 95 & 90 \\
\hline \begin{tabular}{l}
\begin{tabular}{l}
\(\mathrm{W}_{\mathrm{h} 2}\) \\
\(=\mathrm{W}_{\mathrm{h} 1} *\left\{\mathrm{v} / \mathrm{v}_{\mathrm{nom}}\right\}^{1.6}\)
\end{tabular} \\
\hline
\end{tabular} & & & & & \\
\hline \begin{tabular}{l}
\(\mathrm{W}_{\mathrm{e} 2}=\mathrm{W}_{\mathrm{e} 1} *\left\{\mathrm{~V} / \mathrm{v}_{\mathrm{nom}}\right.\) \\
\(\}^{2}\)
\end{tabular} & & & & & \\
\hline \(\mathrm{~W}_{\mathrm{i}}=\mathrm{W}_{\mathrm{h}}+\mathrm{W}_{\mathrm{e}}\) & & & & & \\
\hline
\end{tabular}

\section*{RESULT}

Separated the core losses into hysteresis loss and eddy current loss by conducting no load test, keeping V/F constant on a \(1 \phi\) transformer.

\section*{ASSESSMENT RUBRICS}
\begin{tabular}{|c|c|c|c|c|}
\hline Preliminary Work & Implementing the Work/Conducting the Experiment & Calculations, Result and Inference & Viva voce & Record Submission \\
\hline 5 & 5 & 5 & 10 & 5 \\
\hline & & & & \\
\hline \begin{tabular}{l}
Total Marks scored \& \\
Signature of Faculty
\end{tabular} & \multicolumn{4}{|l|}{} \\
\hline
\end{tabular}

\section*{CIRCUIT DIAGRAM}

\(\qquad\)

\section*{SUMPNER'S TEST ON TRANSFORMERS}

\section*{AIM}

To conduct Sumpner's test on a pair of identical single-phase transformers

\section*{OBJECTIVE:}

To
1) Predetermine the efficiency and regulation of a given single phase Transformer at different load conditions and power factor
2) Plot efficiency vs output \&regulation vs power factor curves
3) Obtain the equivalent circuit of the transformer referred to LV \&HV sides

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|c|c|c|c|}
\hline No & Equipments & Specification & Quantity \\
\hline 1 & Auto Transformer & \(230 /(0-270) \mathrm{V}\) & 2 \\
\hline 2 & Ammeter & \(0-2 \mathrm{~A} \mathrm{MI}\) & 1 \\
\hline 3 & Voltmeter & \(0-600 \mathrm{~V} \mathrm{MI}\) & 1 \\
\hline 4 & Wattmeter & \(150 \mathrm{~V}, 2 \mathrm{~A}, \mathrm{LPF}\) & 2 \\
\hline 5 & Ammeter & \(0-5 \mathrm{~A} \mathrm{MI}\) & 1 \\
\hline 6 & Voltmeter & \(0-150 \mathrm{~V} \mathrm{MI}\) & 1 \\
\hline 7 & Wattmeter & \(150 \mathrm{~V}, 2 \mathrm{~A}, \mathrm{UPF}\) & 1 \\
\hline 8 & Voltmeter & \(0-75 \mathrm{~V} \mathrm{MI}\) & 1 \\
\hline
\end{tabular}

\section*{PRINCIPLE}

When 2 identical transformers are available, we can conduct a back-to-back test on that set known as sumpner's test. This test provides the data for equivalent circuit regulation and efficiency curve. More over temperature under load condition can be checked. Though both the machines are loaded to full load, the power drawn from the main is to supply total losses and is negligibly small. The primaries are connected in parallel and energized at rated voltage and frequency with open secondary. Input power equals twice the core loss. The tw se se verifaried are connected in series with their polarities in phase opposition. This can bpqhechoâl. Vage

\section*{TABULAR COLUMN}
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline \(\mathrm{V}_{0}\) & \(\mathrm{I}_{0}=\mathrm{I}_{1} / 2\) & \multicolumn{2}{|l|}{\(\mathrm{W}_{\mathrm{O}}\) (watts)} & \[
\begin{aligned}
& \hline \mathrm{V}_{\mathrm{sc}}= \\
& \mathrm{V}_{2} / 2 \\
& \hline
\end{aligned}
\] & Isc & \multicolumn{2}{|l|}{\(\mathrm{W}_{\text {Sc }}\) (watts)} \\
\hline (V) & (A) & OBSERVED & ACTUAL & (V) & (A) & OBSERVED & ACTUAL \\
\hline & & & & & & & \\
\hline
\end{tabular}

To find Efficiency
\begin{tabular}{|l|l|l|l|l|l|l|l|}
\hline \begin{tabular}{l} 
SI \\
no.
\end{tabular} & \begin{tabular}{l} 
Power \\
factor
\end{tabular} & \begin{tabular}{ll} 
Core \\
Loss \\
Wo
\end{tabular} & \begin{tabular}{l} 
Coppe \\
r loss \\
Wc
\end{tabular} & \begin{tabular}{l} 
Total \\
loss
\end{tabular} & \begin{tabular}{l} 
Output \\
power
\end{tabular} & \begin{tabular}{l} 
Input \\
power
\end{tabular} & \(\boldsymbol{\eta}\) \\
\hline & & & & & & \\
\hline
\end{tabular}
voltmeter reading which should give zero reading. Switch can be now closed and we can apply a very low voltage to the secondary such that ammeter reads rated secondary current. Wattmeter in the secondary side gives twice the full load copper loss and the corresponding voltmeter reading will be 2 V s while the primary current will be 2Io
Hence \(\mathrm{Wi}=\mathrm{W}_{1} / 2\)
\[
\mathrm{Wsc}=\mathrm{W}_{2} / 2
\]

Io \(=\mathrm{I}_{1} / 2\)
\[
\mathrm{Isc}=\mathrm{I}_{2}
\]
\(\mathrm{Vo}=\mathrm{V}_{1} \quad \mathrm{Vsc}=\mathrm{V}_{2} / 2\)

\section*{PRECAUTIONS:}
1. Auto Transformer should be kept in zero position, before switching on the ac supply.
2. Transformer should be operated under rated values.

\section*{PROCEDURE}
1. Connections are made as shown in the circuit diagram.
2. Rated voltage of 110 V is adjusted in voltmeter by adjusting the autoTransformer which would be in zero before switching on the supply at the primary side.
3. The readings of voltmeter, ammeter and wattmeter are noted on the primary side.
4. A voltmeter is connected across the secondary and with the secondary supply off i.e switch \(S\) is kept open. The voltmeter reading is noted.
5. If the reading of voltmeter reads higher voltage, the terminals of any one of the coils is interchanged in order that voltmeter reads zero.
6. The secondary is now switched on and SPST switch is closed with variac of auto transformer is zero.
7. After switching on the secondary the variac of transformer (Auto) is adjusted so that full load rated secondary current flows.
8. Then the readings of wattmeter, Ammeter and voltmeter are noted.
9. The percentage efficiency and percentage regulation are calculated and equivalent circuit is drawn.

\section*{SAMPLE CALCULATION:}

\section*{Efficiency:}

Core loss \(=W_{0}=\)
Load fraction \(=\mathrm{x}=\)
Full load cu loss \(=W_{\text {sc }}=\)
Cu loss at load fraction \(\mathrm{x}=\mathrm{x}^{2} \mathrm{~W}_{\mathrm{sc}}=\)
Total loss \(=\) Core loss +Cu loss \(=\)
Output \(=\mathrm{V} \operatorname{I} \operatorname{Cos} \varphi=\)
Input \(=\) output + total loss \(=\)
\% Efficiency =
output/input *100

\section*{Power Factor On}

No Load:
\(\operatorname{Cos} \Phi=\left(\mathrm{W}_{\mathrm{o}} / \mathrm{V}_{\mathrm{o}} \mathrm{I}_{\mathrm{o}}\right)\)
Working component \(\mathrm{I}_{\mathrm{W}}=\mathrm{I}_{\mathrm{O}} * \operatorname{Cos} \Phi\)
Magnetizing component \(\mathrm{I} \mu=\mathrm{I}_{\mathrm{O}} * \operatorname{Sin} \Phi\)
Resistance \(\mathrm{R}_{\mathrm{o}}=\mathrm{V}_{\mathrm{o}} / \mathrm{I}_{\mathrm{w}}\) in \(\Omega\)
Magnetising reactance \(\mathrm{X}_{\mathrm{O}}=\mathrm{V}_{\mathrm{O}} / \mathrm{I}_{\mathrm{m}}\)
From Short Circuit Test:
Equivalent resistance \(\mathrm{R}_{02}=\mathrm{W}_{\mathrm{sc}} / \mathrm{I}_{\mathrm{sc}}{ }^{2}\) in \(\Omega=\)
Equivalent impedance \(\mathrm{Z}_{02}=\mathrm{V}_{\mathrm{sc}} / \mathrm{I}_{\mathrm{sc}}\) in \(\Omega=\)
Equivalent leakage reactance \(\mathrm{X}_{02}=\sqrt{ }\left(\mathrm{Z}_{02}{ }^{2}-\mathrm{R}_{02}{ }^{2}\right)\) in \(\Omega=\)
Voltage ratio \(\mathrm{K}=\mathrm{V}_{2} / \mathrm{V}_{1}=\)
\(\mathrm{R}_{01}=\mathrm{R}_{02 / \mathrm{K}}{ }^{2}=\)
\[
\mathrm{X}_{01}=\mathrm{X}_{02} / \mathrm{K}^{2}=
\]

Percentage of Regulation
For Lagging PF, \%Regulation \(=\mathrm{X}\left(\mathrm{I}_{2} \mathrm{R}_{02} \operatorname{Cos} \Phi+\mathrm{I}_{2} \mathrm{X}_{02} \operatorname{Sin} \Phi\right)^{\text {Signature Not Verified }}\)
For Leading PF, \%Regulation \(=\mathrm{X}\left(\mathrm{I}_{2} \mathrm{R}_{02} \operatorname{Cos} \Phi-\mathrm{I}_{2} \mathrm{X}_{02} \operatorname{Sin} \Phi\right)\) Principal. VJEC

To find Regulation
\begin{tabular}{|l|l|l|l|l|l|l|}
\hline Load & \(\operatorname{Cos} \varphi\) & \(\operatorname{Sin} \varphi\) & \begin{tabular}{c}
\(\mathrm{I}_{2} \mathrm{R}_{02}\) \\
\(\operatorname{Cos} \varphi\)
\end{tabular} & \(\mathrm{I}_{2} \mathrm{X}_{02}\) \\
\(\operatorname{Sin} \varphi\)
\end{tabular}

VIVA

\section*{RESULT}

Efficiency and regulation of a given single phase transformer are determined byconducting back-to-back test.

\section*{ASSESSMENT RUBRICS}


\section*{CIRCUIT DIAGRAM}


\section*{Specification of transformers}

Transformer 1
Primary volt \(=\)
Secondary volt \(=\)
\(--\mathbf{k V A}=\)

Transformer 2
Primary volt \(=\)
Secondary volt \(=\)
\(\mathrm{kVA}=\)
\(\qquad\)

\section*{PARALLEL OPERATION OF TWO DISSIMILAR SINGLE PHASE TRANSFORMER}

\section*{AIM}

To perform parallel operation of two dissimilar single phase transformers.

\section*{OB,JECTIVES:}
a) To determine the load sharing of each transformer by their equivalent impedances
b) To verify the load sharing by actual measurements

\section*{EOUIPMENTS REOUIRED}
\begin{tabular}{|l|l|l|l|}
\hline NO & EQUIPMENTS & SPECIFICATION & QUANTITY \\
\hline 1 & & & \\
\hline 2 & & & \\
\hline 3 & & & \\
\hline 4 & & & \\
\hline 5 & & & \\
\hline
\end{tabular}

\section*{PRINCIPLE}

Let us consider two transformers of equal voltage ratios for parallel connection. Let \(\mathrm{Z1}, \mathrm{Z} 2\) be their impedance. Let us assume that no load voltage of both the secondaries is the same. That is \(\mathrm{E} 1=\mathrm{E} 2=\mathrm{E}\). and that the two voltages are coincident. Under these conditions, both primaries and secondaries of both transformers can be connected in parallel and no circulating current will flow on load. The equivalent circuit is shown below


\section*{TABULAR COLOUMN}
\begin{tabular}{|c|c|c|c|c|c|}
\hline V1 & V2 & I1 & I2 & I3 & I4 \\
\hline & & & & & \\
\hline
\end{tabular}
\begin{tabular}{|c|c|c|c|}
\hline Transformer & \(\mathbf{V}_{\text {sc }}\) & \(\mathbf{I}_{\text {sc }}\) & \(\mathbf{Z}\) \\
\hline & & & \\
\hline & & & \\
\hline
\end{tabular}

From above circuit, \(I_{1} Z_{1}=I_{2} Z_{2}=I Z_{12}\)
\(\frac{1}{Z_{12}}=\frac{1}{Z_{1}}+\frac{1}{Z_{2}}\)
Therefore \(Z_{12}=\frac{Z_{1} Z_{2}}{Z_{1}+Z_{2}}\)
From equation \(1, I_{1}=\frac{I Z_{12}}{Z_{1}}=\frac{I Z_{2}}{Z_{1}+Z_{2}}\)
And \(I_{2}=\frac{I Z_{12}}{Z_{2}}=\frac{I Z_{1}}{Z_{1}+Z_{2}}\)
Multiplying \(V_{2}, I_{1} V_{2}=V_{2} * \frac{I Z_{2}}{Z_{1}+Z_{2}} \quad\) and \(\quad I_{2} V_{2}=V_{2} * \frac{I Z_{1}}{Z_{1}+Z_{2}}\)
That is \(\quad \mathrm{V}_{2} \mathrm{I}\) is the combined load \(\mathrm{KVA}=\mathrm{Q}\)
\(\mathrm{V}_{2} \mathrm{I}_{1} \quad\) Is the load KVA carried by first transformer \(=\mathrm{Q}_{1}\)
\(\mathrm{V}_{2} \mathrm{I}_{2}\) Is the load KVA carried by second transformer \(=\mathrm{Q}_{2}\)
That is \(Q_{1}=\frac{Q Z_{2}}{Z_{1}+Z_{2}} \quad\) and \(\quad Q_{2}=\frac{Q Z_{1}}{Z_{1}+Z_{2}}\)

\section*{PROCEDURE}

The primary of the two transformers are connected in parallel across the supply as shown. The secondary's are also connected in parallel. It is noted that terminals of similar polarity are connected. The whole connections are made as shown in the circuit diagram. The readings of the meters at no load are noted. Now the switch s is closed and the transformers are loaded a little. Readings are noted. From this the load shared by each transformer is determined. To determine the load shared by each transformer their impedance must be formed out. For this short circuit test is conducted on each transformer.

\section*{SAMPLE CALCULATION:}

Impedance of first transformer
Impedance of second transformer
Total load
\[
\mathrm{Q}=\mathrm{V} 2 * \mathrm{I} 4=
\]

Theoretical load shared by first transformer \(=\frac{Q Z_{2}}{Z_{1}+Z_{2}}=\)

Actual load shared by first transformer
\[
=\mathrm{V} 2 * \mathrm{~A} 3=
\]

Theoretical load shared by second transformer \(\quad=\frac{I Z_{1}}{Z_{1}+Z_{2}}\)

Actual load shared by second transformer
\[
=\mathrm{V} 2 * \mathrm{~A} 2
\]

VIVA

\section*{RESULT}

Performed parallel operation of two dissimilar single-phase transformers and the following objectives are achieved
- Determined the load sharing of each transformer by their equivalent impedances
- Verified the load sharing by actual measurements

\section*{ASSESSMENT RUBRICS}
```


[^0]:    enter highest degree of the polynomial 1: 3
    Enter the coefficeint of $x^{\wedge} 0: 1$
    Enter the coefficeint of $x^{\wedge} 1: 4$
    Enter the coefficeint of $x^{\wedge} 2: 3$
    Enter the coefficeint of $x^{\wedge} 3: 2$
    enter the highest degree of the polynomial 2:5
    enter the coefficient of $\mathrm{x}^{\wedge} 0: 3$
    enter the coefficient of $x^{\wedge} 1: 4$
    enter the coefficient of $x^{\wedge} 2: 2$
    enter the coefficient of $x^{\wedge} 3: 1$
    enter the coefficient of $x^{\wedge} 4: 5$
    enter the coefficient of $x^{\wedge} 5: 6$
    poly1: $1+1 x^{\wedge} 0+4 x^{\wedge} 1+3 x^{\wedge} 2+2 x^{\wedge} 3$
    poly2: $3+3 x^{\wedge} 0+4 x^{\wedge} 1+2 x^{\wedge} 2+1 x^{\wedge} 3+5 x^{\wedge} 4+6 x^{\wedge} 5$
    Polynomial after addition: $4+8 x^{\wedge} 1+5 x^{\wedge} 2+3 x^{\wedge} 3+5 x^{\wedge} 4+6 x^{\wedge} 5$

