



# ALAGAPPA UNIVERSITY

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(A State University Established by the Government of Tamil Nadu)

KARAIKUDI – 630 003



## Directorate of Distance Education

**M.Sc. [Physics]**

**II - Semester**

**345 24**

# ADVANCED ELECTRONICS AND PHYSICS LABORATORY - II

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E-28, Sector-8, Noida - 201301 (UP)

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**Work Order No. AU/DDE/DE1-291/Preparation and Printing of Course Materials/2018 Dated 19.11.2018 Copies - 500**

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# SYLLABI-BOOK MAPPING TABLE

## Advanced Electronics and Physics Laboratory - II

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### Syllabi

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1. Half Adders and Full Adders.
2. Integrator and Differentiator Circuits using IC 741.
3. Active Filters Using IC 741.
4. D/A Converters (a) Ladder Network (b) Weighted Resistor Method.
5. A/D Converter.
6. Encoder-Decoder Circuits.
7. Square Wave, Sine Wave and Triangular Wave Generators using IC.
8. Multiplexer Circuits.
9. Flip-Flop Circuits using IC.
10. Powder Photograph-X-Ray Method.
11. Resistivity Measurements of Thin Films.
12. Hall Effect-Mobility and Hall Constant Determination.
13. Dielectric Constant-Microwave Frequency using Klystron.
14. Determination of Curie Point-Ferromagnetic Material.
15. Susceptibility by Guoy's Method.
16. Susceptibility by Quincke's Method.
17. Reflection Grating Spectrometer.
18. Any of the Experiments of Equal Standard.

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## INTRODUCTION

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### NOTES

The term *Electronics* has been coined from *electron* - the key particle, flow of which through a conductor gives us electric current or simply current. This current can be produced with the help of batteries and generators - machines which generate electric power either DC or AC at 50 Hz. This current can be put to use for various purposes, such as illumination, heating, driving the motors. The generation, control, transmission and use of both DC and AC at 50 Hz magnitudes ranging from a few microamperes to hundreds of ampere are coming under the purview of so called electrical engineering. The controlled flow of electrons has been used through various techniques and forms what is known as electronics. In modern times, it is very difficult to find anything starting from household goods, transports, health, communication, entertainment, multimedia, internets, where electronics has not made its presence felt.

Electronics, thus, is a branch of physics and electrical engineering that deals with the emission, behaviour, and effects of electrons and with electronic devices. Electronics encompasses an exceptionally broad range of technology. Starting from the fabrication of vacuum tubes to transistors, the science of electronics has moved rapidly to fabricate integrated circuits which in turn have paved the way for generating microprocessors, super computers and the advanced electronics gadgets of the day.

In electronics, a logic gate is an idealized or physical device implementing a Boolean function; that is, it performs a logical operation on one or more binary inputs and produces a single binary output. Logic gates are primarily implemented using diodes or transistors acting as electronic switches, but can also be constructed using vacuum tubes, electromagnetic relays (relay logic), fluidic logic, pneumatic logic, optics, molecules, or even mechanical elements. With amplification, logic gates can be cascaded in the same way that Boolean functions can be composed, allowing the construction of a physical model of all of Boolean logic, and therefore, all of the algorithms and mathematics that can be described with Boolean logic.

Logic circuits include such devices as multiplexers, registers, Arithmetic Logic Units (ALUs), and computer memory, all the way up through complete microprocessors, which may contain more than 100 million gates. In modern practice, most gates are made from Field Effect Transistors (FETs), particularly Metal Oxide Semiconductor Field Effect Transistors (MOSFETs).

Due to the complex nature of electronics theory, laboratory experimentation is considered as the significant measure for the development of electronic devices. These experiments are specifically used for testing or verifying the engineer's design and detecting errors.

This book, *Advanced Electronics and Physics Laboratory – II*, focuses on the engineering aspects of electronics and provides the basic knowledge on electronic circuits, Half adders and Full adders, Integrator and Differentiator circuits using IC 741, D/A converters, A/D converters, Encoder-Decoder circuits, Wave generators using IC, Multiplexer circuits, Flip Flop circuits using IC, Powder photograph – X-ray method, Resistivity measurements of thin films, Hall effect and Hall constant determination, Dielectric constant, Microwave frequency using klystron, Determination of Curie point, Susceptibility by Guoy's method and by Quincke's method.

## 1. HALF ADDERS AND FULL ADDERS.

**Aim:** To design and verify:

- (a) Half Adders
- (b) Full Adders

### Components Required

Following ICs are required.

Sl. No	Item	Quantity
1	IC 7486 (XOR Gate)	01
2	IC 7408 (AND Gate)	01
3	IC 7432 (OR Gate)	01
4	IC 7400 (NAND Gate)	03

### Theory - Half Adder

Addition of two binary bits are done through half adder. The input to the half adder are two bits which generates two outputs, one is a SUM and the other is a CARRY. With inputs to half adder as A and B, the Boolean expression for SUM(S) and CARRY (C) is given as,

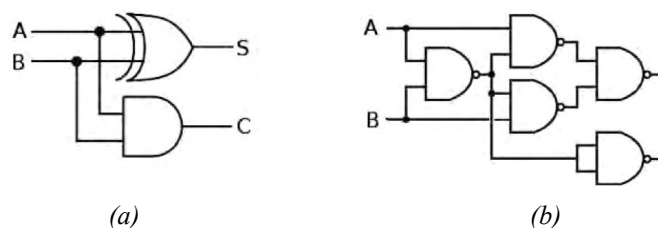
$$S = A \oplus B$$

$$C = A \cdot B$$

The truth table for half adder is given as,

Truth Table of Half Adder			
Input		Output	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

**Circuit Diagram:** In the following Figure 1, (a) Logic circuit of Half Adder and (b) Half Adder using NAND Gates only.



**Fig. 1** (a) Logic Circuit of Half Adder, (b) Half Adder Using NAND Gates Only

## NOTES

**NOTES**

**Theory - Full Adder**

Addition of three binary bits are carried out using full adder circuit. The inputs are two binary inputs and a CARRY-IN inputs. Two outputs SUM and CARRY-OUT are generated. The Boolean expression for a SUM and CARRY for a full adder is given as,

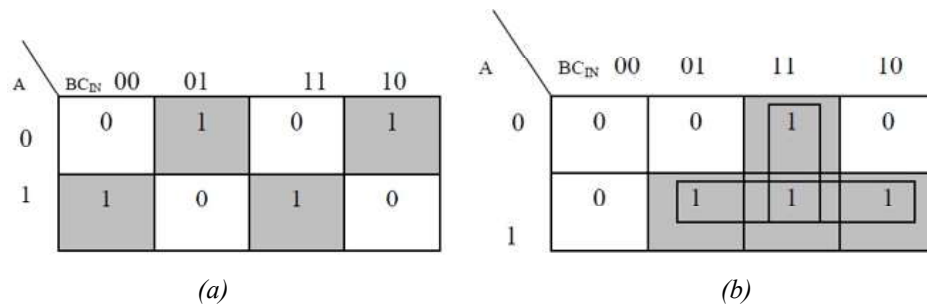
$$SUM = A \oplus B \oplus C_{in}$$

$$CARRY = A \cdot B + C_{in}(A \oplus B)$$

The truth table for a full adder is given as,

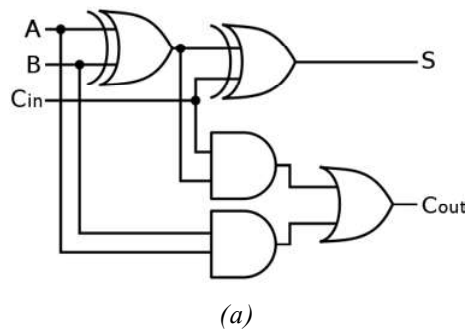
A	B	$C_{in}$	SUM	CARRY
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

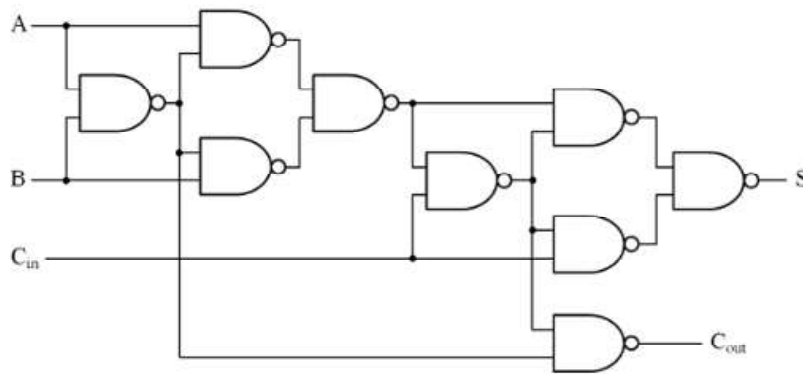
The K-Map reduction of SUM and CARRY are illustrated in Figure 2 (a) and (b), respectively.



**Fig. 2** (a) K-MAP for SUM (b) K-MAP for CARRY

**Circuit Diagram:** In the following Figure 3, (a) Logic Circuit of Full Adder, (b) Full Adder Using NAND Gates Only.





(b)

Fig. 3 (a) Logic Circuit of Full Adder, (b) Full Adder Using NAND Gates Only

**Procedure**

1. Verify whether all the wires and IC components are in good condition.
2. Verify the working of IC using IC tester if available or apply voltages to the different gates of the IC and check the outputs.
3. Set up a half adder circuit as shown above in the breadboard.
4. Supply all the input combinations of voltages as provided in the truth table. It is to be noted that Logic '1' is equivalent to +5V DC voltage and Logic '0' is equivalent to 'GND' voltage.
5. Observe the output corresponding to input combinations and enter it in the Observation Table.
6. Repeat the above steps for FULLADDER circuit.

Truth Table of Half Adder			
Input		Output	
A (Voltage Applied)	B (Voltage Applied)	S (LED ON/OFF)	C (LED ON/OFF)

**NOTES**

NOTES

Truth Table of FULL Adder				
Input			Output	
A (Voltage Applied)	B (Voltage Applied)	$C_{in}$ (Voltage Applied)	S (LED ON/OFF)	C (LED ON/OFF)

**Results**

Record your observations and analyse.

**2. INTEGRATOR AND DIFFERENTIATOR CIRCUITS USING IC 741.**

**Aim:** To study the working of Integrator and Differentiator using OPAMP IC 741.

**Components Required**

Sl. No	Item	Quantity
1	DC Power Supply (0-30V)	01
2	IC 741	01
3	Oscilloscope	01
4	R (1K, 10K, 910 $\Omega$ ), C (0.01 $\mu F$ )	01 Each (For Integrator)
5	R (1K, 100 $\Omega$ ), C (0.01 $\mu F$ , 0.0015 $\mu F$ )	01 Each (For Differentiator)

**Theory**

**Integrator**

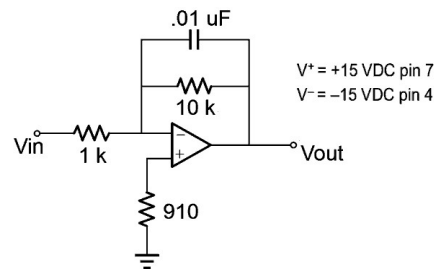
The concept of integration is usually described as ‘Finding the Area under the Curve’. There are many uses for this function, including wave shaping and analog computing. An ordinary amplifier ideally changes only the amplitude of the input signal. An integrator can change the waveform of the input signal, for example, turning a square wave into a triangle wave. A practical integrator cannot be used at just any frequency. There exists a useful range of integration, outside of which the circuit does not produce the desired effect.



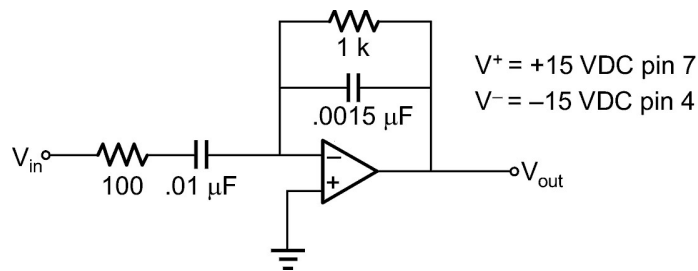
## Differentiator

The concept of differentiation is usually described as 'Finding the Slope of the Curve'. There are many uses for this function, including wave shaping and analog computing. An ordinary amplifier ideally changes only the amplitude of the input signal. A differentiator can change the waveform of the input signal, for example, turning a triangle wave into a square wave. A practical differentiator cannot be used at just any frequency. There exists a useful range of differentiation, outside of which the circuit does not produce the desired effect.

### Circuit Diagrams



*Fig. 1 Integrator*



*Fig. 2 Differentiator*

### Procedure for Integrator

1. Derive the equation for  $V_{out}$  for the circuit of Figure 1. Calculate the lowest usable 'Integratable' frequency,  $f_{low}$ . Record these items in observation Table 1.

The integrable frequency is given as,

$$f_{low} = \frac{1}{2\pi R_f C}$$

Where  $R_f$  is the feedback resistor.

2. Calculate the integrator's output voltage for the following inputs and record them in observation Table 2.
  - 1 volt peak sine wave at 2 times  $f_{low}$
  - 1 volt peak sine wave at 10 times  $f_{low}$

## NOTES

NOTES

- 1 volt peak square wave at 2 times  $f_{low}$
- 1 volt peak square wave at 10 times  $f_{low}$

The output voltage is given as,

$$V_{out}(t) = -\frac{1}{R_{in}C} \int V_{in}(t) dt$$

3. Assemble the integrator circuit.
4. Save the display of the output of the integrator for each of the inputs listed in Step 2, above. Record these Graphs 1 through 4, respectively. It is very important to note the phase of the output waveform with respect to the input waveform.
5. Apply a 1 volt peak sine wave one decade *below*  $f_{low}$ . Save the output signal as Graph 5. Does the circuit appear to be integrating?
6. Apply a 1 volt peak square wave one decade *below*  $f_{low}$ . Save the output signal as Graph 6. Does the circuit appear to be integrating?

**Procedure for Differentiator**

1. Derive the equation for  $V_{out}$  for the circuit of Figure 2. Calculate the highest usable ‘Differentiable’ frequency,  $f_{high}$ . Record these items in observation Table 3.

$$f_{low} = \frac{1}{2\pi R_f C_f}$$

2. Calculate the differentiator’s output voltage for the following inputs and record them in observation Table 4.
  - 1 volt peak sine wave at one-half  $f_{high}$
  - 1 volt peak sine wave at one-tenth  $f_{high}$
  - 1 volt peak triangle wave at one-half  $f_{high}$
  - 1 volt peak triangle wave at one-tenth  $f_{high}$

The output voltage is given as,

$$V_{out}(t) = -R_f C_{in} \frac{dv_{in}(t)}{dt}$$

3. Assemble the differentiator circuit.
4. Save the display of the output of the differentiator for each of the inputs listed in Step 2. Record these Graphs 1 through 4, respectively. It is very important to note the phase of the output waveform with respect to the input waveform.
5. Apply a 1 volt peak sine wave one decade *above*  $f_{high}$ . Save the output signal as Graph 5. Does the circuit appear to be differentiating?

6. Apply a 1 volt peak triangle wave one decade *above*  $f_{\text{high}}$ . Save the output signal as .....

Graph 6. Does the circuit appear to be differentiating?

**Observation Tables**

**Integrator**

*Table 1*

Equation for $V_{\text{out}}$	
$f_{\text{low}}$	

*Table 2*

Input Signal	Output Signal
1 volt peak sine wave at 2 times $f_{\text{low}}$	
1 volt peak sine wave at 10 times $f_{\text{low}}$	
1 volt peak square wave at 2 times $f_{\text{low}}$	
1 volt peak square wave at 10 times $f_{\text{low}}$	

**Differentiator**

*Table 3*

Equation for $V_{\text{out}}$	
$f_{\text{high}}$	

*Table 4*

Input Signal	Output Signal
1 volt peak sine wave at $1/2 f_{\text{high}}$	
1 volt peak sine wave at $1/10 f_{\text{high}}$	
1 volt peak triangle wave at $1/2 f_{\text{high}}$	
1 volt peak triangle wave at $1/10 f_{\text{high}}$	

**Results:** (Insert the observed graphs for Integrator and Differentiator)

**NOTES**

### 3. ACTIVE FILTERS USING IC 741

**Aim:** To design and study the Frequency Response of Second Order Butterworth (Low Pass) Filter with Cutoff Frequency of 1000 Hz.

#### NOTES

#### Components Required

Sl. No	Item	Quantity
1	DC Power Supply (0-30)V	01
2	Oscilloscope	01
3	Function Generator	01
4	IC 741	01
5	C (0.1μF), R (4.7k, 1.2k, 10k)	01 Each
6	R(1.5k, 100Ω)	02 Each

#### Theory

A Filter is a circuit that is designed to pass a specified band of frequencies while attenuating all the signals outside the band. It is a frequency selective circuit. The filters are basically classified as Active Filters and Passive Filters.

The Passive filter networks use only passive elements, such as Resistors, Inductors and Capacitors. Active filter circuits use the active elements, such as Op-Amps, Transistors along with the Resistors, Inductors and Capacitors.

A 'Low Pass Filter' has a constant gain from 0 Hz to a high cutoff frequency  $f_H$ . The circuit allows the range of frequencies from 0 to  $f_H$ . This range is known as Pass Band. The range of frequencies beyond  $f_H$  is completely attenuated and hence called Stop Band.

For a Second Order Butterworth Active Filter the roll-off rate should be either -40db/decade or -12db/octave.

The transfer function expression for a low pass filter is given as,

$$A_v = \frac{V_0}{V_{in}} = \frac{A_0 Y_1 Y_2}{[Y_1 Y_2 + Y_4(Y_1 + Y_2 + Y_3) + Y_2 Y_3(1 - A_0)]}$$

In a low pass filter  $Y_1 = Y_2 = 1/R$  and  $Y_3 = Y_4 = sC$

Therefore,

$$A_v = \frac{(A_0/R^2)}{[(1/R^2) + (3 - A_0)sC/R + (sC/R)^2]}$$

Let  $1/RC = \omega_n$

$$A_v = \frac{(A_0 \omega_n^2)}{[(1) + (3 - A_0)s/\omega_n + (s/\omega_n)^2]}$$

Where  $\omega_n/s$  is the normalized frequency.\

Also, let  $(3 - A_0) = \alpha$ . For maximum flat response  $(3 - A_0)$  should be equal to 1.414.

When  $s = \omega_n$ ,  $A_v = A_0 / \sqrt{2} = A_0 / 1.414$  which gives the half power frequency or cutoff frequency. If the desired cutoff frequency is 1000 Hz,

Then  $1/RC = \omega_n$ .

Let  $C = 0.1 \mu F$ ,  $f_n = 1000 \text{ Hz}$ , then,

$$1000 \text{ Hz} = \frac{1}{2\pi R \times (0.1 \times 10^{-6})} \quad R = 1.6 \text{ k}\Omega$$

From  $(3 - A_0) = 1.414$ , theoretical pass band gain is given as,

$$A_0 = 1.586$$

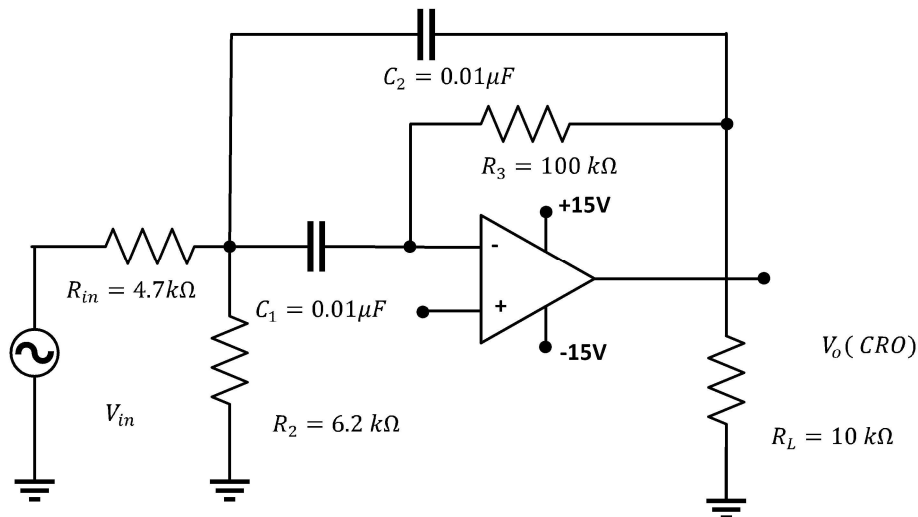
Also, the OPAMP is used in the non-inverting mode and hence,

$$A_0 = 1 + \frac{R_f}{R_{in}} = 1.586$$

$$\frac{R_f}{R_{in}} = 0.586 \quad R_f = 0.586 R_{in}$$

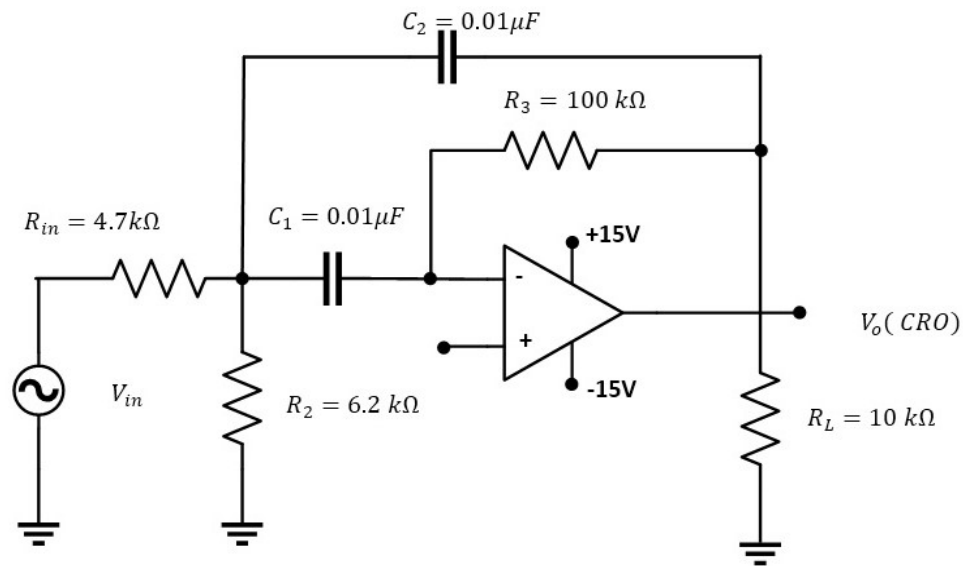
If  $R_{in} = 10 \text{ k}\Omega$ ,  $R_f = 5.86 \text{ k}\Omega \sim (4.7 \text{ k} + 1.2 \text{ k})$

### Circuit Diagram



### NOTES

**NOTES**



*Fig. 1 Circuit Diagram*

**Procedure**

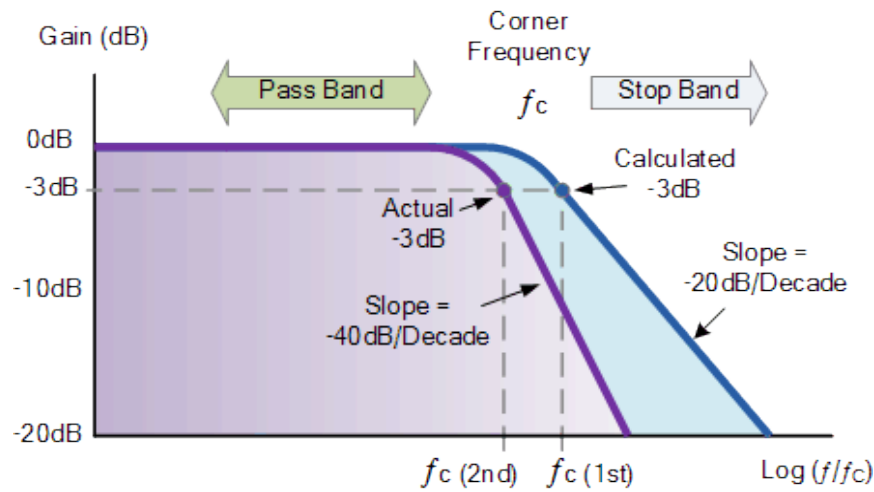
1. Connections can be made as shown in Figure 1 Circuit Diagram above.
2. Set a sinusoidal input with peak voltage as 1V. Change the frequency of function generator in steps of 100 Hz and note down the output amplitude from the CRO.
3. Find the gain in db for each input.
4. Plot the Gain vs. Frequency in Log Graph. Graph should be drawn as shown in Model Graph.
5. Verify if the roll-off rate is -40db/decade or -12db/octave.

**Observation Table**

$V_{in} = \text{_____ } V$

Frequency (Hz)	$V_{out} (V)$	Gain, $A_v (dB) = 20 \log(V_{out} / V_{in})$

## Model Graph



## NOTES

### Results

The Second Order Low Pass Filter was designed and the frequency response plot was drawn. The result are recorded as follows,

Theoretical Cutoff Frequency = \_\_\_\_\_ Hz

Practical Cutoff Frequency = \_\_\_\_\_ Hz

## 4. D/A CONVERTERS (A) LADDER NETWORK (B) WEIGHTED RESISTOR METHOD.

**Aim:** To convert a 4 bit Digital Input Signal to an Analog Voltage and/or Current Signal using,

- R-2R Ladder Network
- Weighted Resistor Method

### Components Required

Sl. No	Item	Quantity
1	DC Power Supply (0-30)V	01
2	Digital Multimeter	01
3	Digital Trainer Board	01
4	IC 741	01
5	R (1k - 2k - 4k, 8k)	04 06 01 Each
6	Connecting Wires	

## NOTES

### Theory

Digital systems are used in ever more applications, because of their increasingly efficient, reliable, and economical operation with the development of the microprocessor, data processing has become an integral part of various systems. Data processing involves transfer of data to and from the microcomputer via input/output devices. Since digital systems, such as microcomputers use a binary system of 1s and 0s, the data to be put into the microcomputer must be converted from analog to digital form. On the other hand, a Digital-to-Analog Converter (DAC) is used when a binary output from a digital system must be converted to some equivalent analog voltage or current. The function of DAC is exactly opposite to that of an ADC.

A DAC in its simplest form uses an Op-Amp and either binary weighted resistors or R-2R ladder resistors. In binary-weighted resistor Op-Amp is connected in the inverting mode, it can also be connected in the non-inverting mode. Since the number of inputs used is four, the converter is called a 4-bit binary digital converter.

### Design

#### 1. Weighted Resistor DAC

$$V_0 = -R_f \left[ \frac{b_A}{8R} + \frac{b_B}{4R} + \frac{b_C}{2R} + \frac{b_D}{R} \right]$$

For a digital input of 1111,  $R_f = R = 4.7k\Omega$

$$V_0 = -\frac{R_f}{R} \left[ \frac{1}{8} + \frac{1}{4} + \frac{1}{2} + \frac{1}{1} \right] \times 5V$$

$$V_0 = -9.375V$$

#### 2. R-2R Ladder Network

$$V_0 = -R_f \left[ \frac{b_A}{16R} + \frac{b_B}{8R} + \frac{b_C}{4R} + \frac{b_D}{2R} \right] \times 5V$$

For a digital input of 1111,  $R_f = R = 4.7k\Omega$

### Circuit Diagram

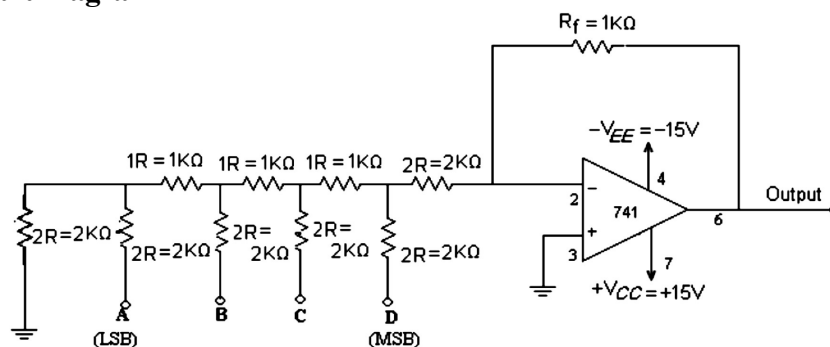
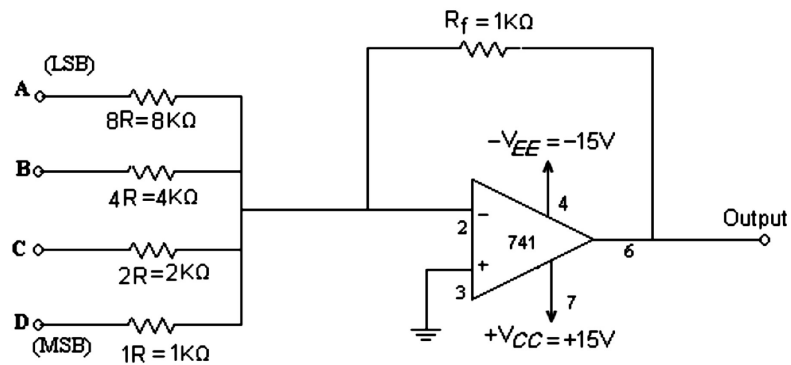


Fig. 1 R-2R Ladder





*Fig. 2 Weighted Ladder Network*

**Procedure**

1. Connect the circuit as shown in Figure 1.
2. Vary the inputs A, B, C, D from the digital trainer board and note down the output at pin 6 of IC 741 OPAMP. For logic '1', +5 V is applied and for logic '0', 0 V(Gnd) is applied.
3. Repeat the above two steps for R – 2R ladder DAC shown in Figure 2.

**Observation Table**

**Weighted Resistor DAC**

S. No	$S_1$	$S_2$	$S_3$	$S_4$	Theoretical Voltage (V)	Practical Voltage (V)
1	0	0	0	0		
2	0	0	0	1		
3	0	0	1	0		
4	0	0	1	1		
5	0	1	0	0		
6	0	1	0	1		
7	0	1	1	0		
8	0	1	1	1		
9	1	0	0	0		
10	1	0	0	1		
11	1	0	1	0		
12	1	0	1	1		
13	1	1	0	0		
14	1	1	0	1		
15	1	1	1	0		
16	1	1	1	1		

**NOTES**

**R-2R Ladder DAC**

**NOTES**

S. No	$S_1$	$S_2$	$S_3$	$S_4$	Theoretical Voltage (V)	Practical Voltage (V)
1	0	0	0	0		
2	0	0	0	1		
3	0	0	1	0		
4	0	0	1	1		
5	0	1	0	0		
6	0	1	0	1		
7	0	1	1	0		
8	0	1	1	1		
9	1	0	0	0		
10	1	0	0	1		
11	1	0	1	0		
12	1	0	1	1		
13	1	1	0	0		
14	1	1	0	1		
15	1	1	1	0		
16	1	1	1	1		

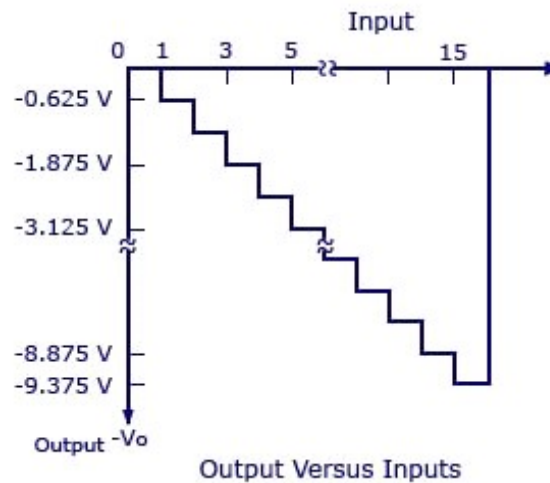
**Results**

Obtain a graph of Input vs. Output voltage as shown in Model Graph.

Outputs of binary weighted resistor DAC and R-2R ladder DAC to be observed and recorded.

NAME	THEORETICAL	PRACTICAL
4-bit DAC R-2R LADDER		
4-bit WEIGHTED DAC		

**Model Graph**



## 5. A/D CONVERTER.

**Aim:** To convert an Analog Input Signal to Digital Output Signal using flash type Analog-to-Digital Converter (ADC).

### Components Required

Sl. No	Item	Quantity
1	DC Power Supply (0-30)V	01
2	Digital Multimeter	01
3	Digital Trainer Board	01
4	ICs LM324, NOT Gate (7404), OR Gate (7432), AND Gate(7408)	01 Each
5	R (1k)	04
6	Connecting Wires	

### Theory

Flash Type ADC is based on the principle of comparing analog input voltage with a set of reference voltages. To convert the analog input voltage into a digital signal of n-bit output,  $(2^n - 1)$  comparators are required.

The three Op-Amps are used as comparators. The non-inverting inputs of all the three comparators are connected to the analog input voltage. The inverting terminals are connected to a set of reference voltages  $(V_{CC}/4)$ ,  $(2V_{CC}/4)$  and  $(3V_{CC}/4)$ , respectively, which are obtained using a resistive divider network and power supply  $+V_{CC}$ .

The output of the comparator is in positive saturation, i.e., Logic 1, when voltage at non-inverting terminal is greater than voltage at inverting terminal and is in negative saturation otherwise.

### Advantages

- It is the fastest type of ADC because the conversion is performed simultaneously through a set of comparators, hence referred as flash type ADC. Typical conversion time is 100ns or less.
- The construction is simple and easier to design.

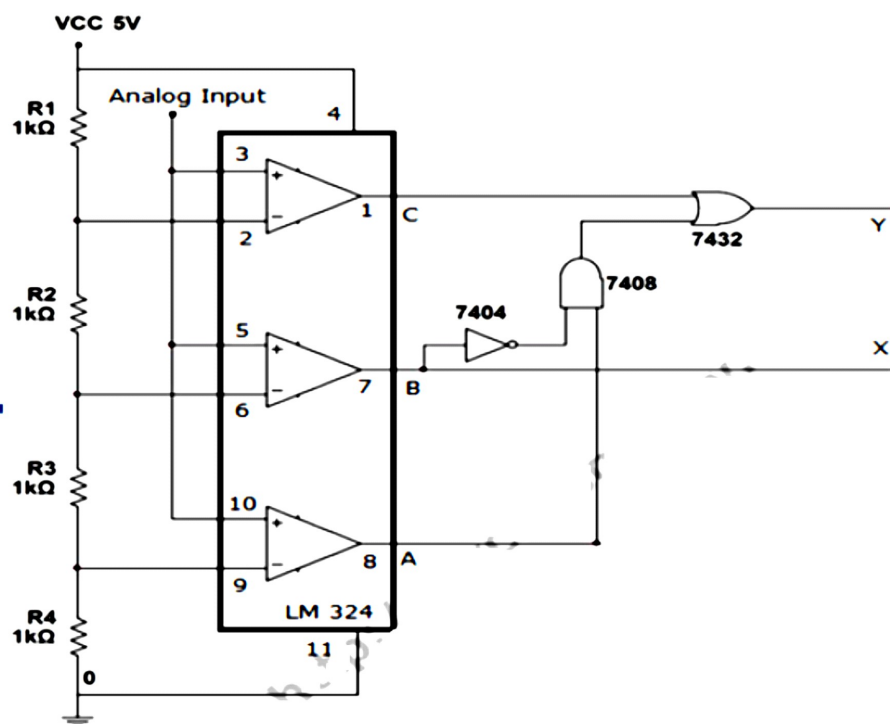
### Disadvantages

- It is not suitable for higher number of bits.
- To convert the analog input voltage into a digital signal of n-bit output,  $(2^n - 1)$  comparators are required. The number of comparators required doubles for each added bit.

### NOTES

## Circuit Diagram

### NOTES



*Fig. 1 Two Bit Flash Type ADC*

### Procedure

1. Connect the circuit as shown in Figure 1.
2. Provide a reference voltage  $V_{CC} = 5V$  using a DC power supply.
3. Provide an analog ac input using a function generator at PINS 3, 5 and 10 of LM324 IC.
4. Change the analog input voltage in the ranges shown in Observation Table and observe/record the output.
5. The output voltage of +5V indicates digital '1' and output voltage less than 5V indicate digital '0'.

### Observation Table

Analog Input	A	B	C	Digital Output	
				X	Y
0 to $\frac{V_{CC}}{4}$	0	0	0		
$\frac{V_{CC}}{4}$ to $\frac{2V_{CC}}{4}$	0	0	1		
$\frac{2V_{CC}}{4}$ to $\frac{3V_{CC}}{4}$	0	1	1		
$\frac{3V_{CC}}{4}$ to $V_{CC}$	1	1	1		

### NOTES

### Results

Record and analyse the recorded result.

### 6. ENCODER - DECODER CIRCUITS

**Aim:** To implement a Decoder and an Encoder Circuit.

### Components Required

Sl. No	Item	Quantity
1	DC Power Supply (0-30)V	01
2	Digital Multimeter	01
3	Digital Trainer Board	01
4	ICs NOT Gate (7404), OR Gate (7432), AND Gate(7408)	01 01 01
5	Connecting Wires	

### Theory

Combinational logic circuit are digital circuits made up of Gates and Inverters. An example of this type is the Exclusive OR Circuit implemented using different Logic Gates consisting of AND, OR and NOT. The other most common type of combinational circuit are Decoders, Multiplexers, Comparators and Convertors.

NOTES

A widely used type of Decoder is the BCD to Decimal Decoder, the input to the Decoder is a parallel 4-Bit Binary number from 0000 through 1001 and the circuit provides ten discrete outputs representing decimal numbers 0 through 9. The output of such a Decoder is generally used to operate a seven segment numeric number display. Some additional codes that can be implemented using Decoder Circuit are 8-4-2-1 Binary Code (Natural BCD), Excess-3 Code and Gray Code. Normally, 4 bits are required to represent the decimal digits 0 to 9 in these codes. Though the codes can represent till decimal 16 value, the codes corresponding to decimal values from 10 to 15 are ignored since the decimal number ranges from 0 to 9 only. In this experiment, a 2 bit Encoder is designed. In general, a Decoder is a combinational circuit that converts  $n$ -bit binary input lines into  $2^n$  output lines such that output line will be activated for only one of possible combination of inputs. The outputs are selected based on two select inputs. The inputs AB are decoded into four digits output each representing one of min terms of two input variables.

An Encoder is a combinational logic circuit that essentially performs a 'Reverse' Decoder function. An Encoder accepts an active ONE input representing a digit, such as a decimal digit or octal digit and converts it to a coded output, such as a Binary or BCD. Encoders can be designed to encode various symbols and alphabetic characters. This process of converting from familiar symbols or numbers to a coded format is called 'Encoding'. In general, an Encoder is a combinational logic circuit that has  $2^n$  input lines and  $n$  output lines. As an example, consider a Four Input and Two Output Encoder. It is assumed that only one input has '1' at any given time. From Truth Table, it is obvious that the 'Output' is '1' for A when the 'Input' is 2 and 3; B is '1' when the Input is 1 and 2.

Circuit Diagram

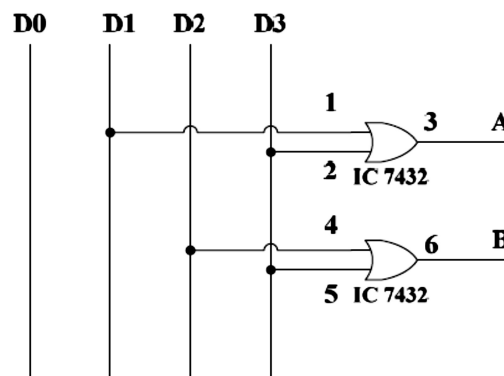


Fig. 1 4 × 2 Encoder

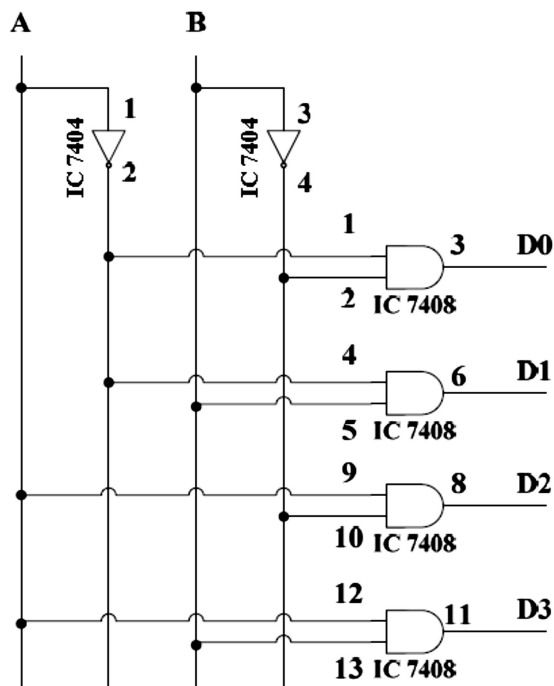


Fig. 2  $2 \times 4$  Decoder

NOTES

**Procedure**

1. Make the circuit connection as shown in the circuit diagrams of Figures 1 and 2.
2. Apply the voltage from the DC regulated power supply at the input pins of the IC according to the Truth Table.
  - (a) Apply +5V for Digital '1'
  - (b) Apply 0V for Digital '0'
3. Measure the output voltage across the output pin of the IC using multimeter.
  - (a) If the output voltage is +5V, then enter Digital '1' in the Observation Table.
  - (b) If the output voltage is 0V, then enter Digital '0' in the Observation Table.
4. Verify the output for all possible input combinations.

NOTES

**Observation Tables**

**4 × 2 Encoder**

Input				Output	
D0	D1	D2	D3	A	B
1	0	0	0	0	0
0	1	0	0	0	1
0	0	1	0	1	0
0	0	0	1	1	1

$A = D2 + D3$

$B = D1 + D3$

**2 × 4 Decoder**

Input		Output			
A	B	D0	D1	D2	D3
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1

$D0 = A'B'$

$D1 = A'B$

$D2 = AB'$

$D3 = AB$

**Results**

Record and analyse the recorded result.

**7. SQUARE WAVE, SINE WAVE AND TRIANGULAR WAVE GENERATORS USING IC.**

**Aim:** To generate Square Wave using OPAMP known as Schmitt Trigger Circuit, Sine Wave using OPAMP using Oscillator Circuit and Triangular Wave using Integrator Circuit.



## Components Required

Sl. No	Item	Quantity
1	DC Power Supply (0-30)V	01
2	Digital Multimeter	01
3	ICs OPAMP (LM324)	01
	R(10k $\Omega$ )	02
	R(100k $\Omega$ )	04
	R(22k $\Omega$ , 220k $\Omega$ ), C(1 $\mu$ F, 33nF, 10nF)	01 Each
	Potentiometer (100k $\Omega$ )	01
4	Connecting Wires	
5	Oscilloscope	01

## NOTES

### Theory

OPAMP is used to generate the Sine, Square and Triangular Waves. The complete experimental setup consists of three stages. The first stage is a Schmitt Trigger setup to generate Square Wave, the second stage is an Integrator that converts the Square Wave to The Triangular Wave. The third stage also consists of the Integrator Circuit that converts the Triangular Waveform to the Sinusoidal Waveform.

A function generator is an electronic device that can produce a variety of different waveforms. The one we will build can Output Square, Triangle, or Sine Waveforms. Like standard function generators, the circuit allows for frequency adjustment; we get ours through a Potentiometer. The circuit can also easily allow for Amplitude Adjustment.

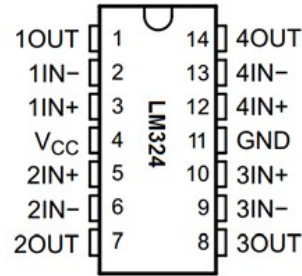
The circuit works on the principle of just using Op-Amps. In this experiment, OPAMP LM324 is used. The LM324 is a Quad Op-Amp, meaning it's composed of 4 independent Op-Amps.

In this circuit, the first Op-Amp produces a Square Wave. After that, the circuit uses two Integrator Circuits to convert the Square Wave into Triangle and Sine Wave Signals.

## Circuit Diagrams

### PIN Diagram for LM324

#### NOTES



*Fig. 1 PIN Diagram of LM 324 (Quad OPAMP)*

The IC LM324 consists of 4 OPAMPs as number above shown in Figure 1, in the pin configuration. The LM324 has two power pins, Pin 4 and Pin 11.

Pin 4 is the positive voltage power supply,  $V_{CC}$ . To this pin, we connect the positive voltage. This establishes the positive DC voltage rail for the circuit.

Pin 11, labeled GND, is the negative voltage power supply. To this pin, we connect the negative voltage. This establishes the negative DC voltage rail for the circuit.

Through these two pins, we establish the positive and negative DC rails from the AC signal can swing.

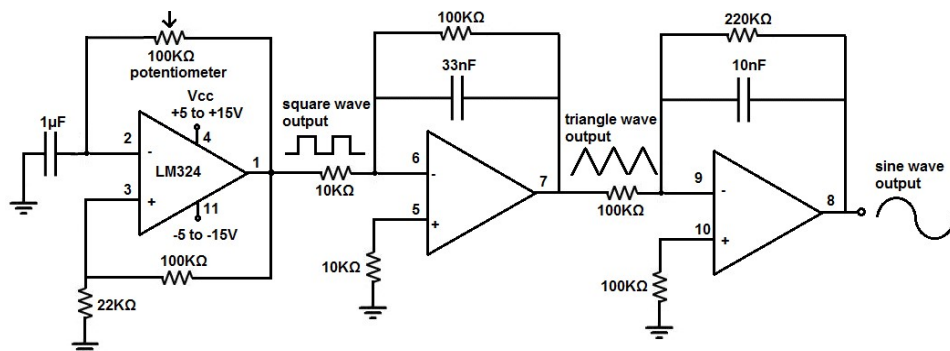
The LM324 can take in a maximum of up to 30V to Pin 4,  $V_{CC}$ .

All of the other 12 pins of the LM324 are the inputs or output of each of the operational amplifiers.

There are 4 operational amplifiers within the chip. Each Op-Amp has 2 inputs and 1 output.

On the Pin OUT above, the Op-Amps are labeled 1, 2, 3, or 4.

The 2 inputs for each Op-Amp are labeled IN- or IN+. The IN- pin refers to the inverting terminal of the Op-Amp. The IN+ pin refers to the non-inverting terminal of the Op-Amp. The OUT terminal refers to the output of the Op-Amp.



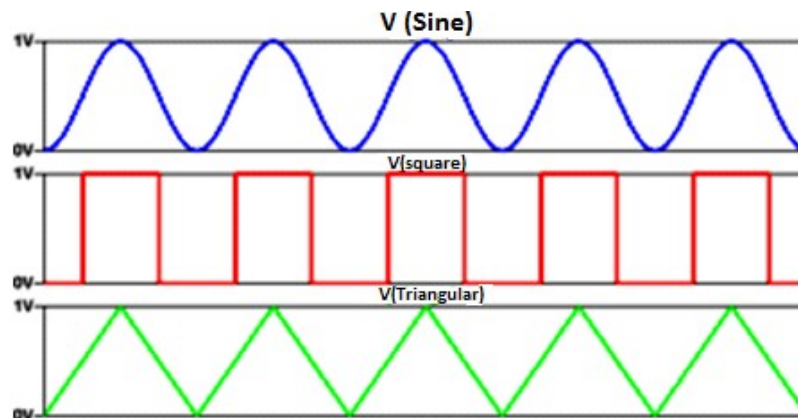
*Fig. 2 Generation of Square, Triangular and Sine Wave using OPAMP*

## Procedure

1. Make the circuit diagram in the breadboard as shown in Figure 2.
2. Adjust the 100k $\Omega$  potentiometer to obtain the Pure Square Wave of desired frequency.
3. Using an oscilloscope observe the waves at Pin 1 and Pin 7 to compare the Square Waveform and the Triangular Waveform.
4. Observe the Sinusoidal Waveform at Pin 8 as above.

## NOTES

## Sample/Model Graph



## Results

Record and analyse the recorded result.

## 8. MULTIPLEXER CIRCUITS.

**Aim:** To design and verify the Truth Table of a  $4 \times 1$  Multiplexer and  $1 \times 4$  Demultiplexer.

## Components Required

S. No.	Name of the Apparatus	Range	Quantity
1.	Digital IC Trainer Kit		1
2.	OR Gate	IC 7432	
3.	NOT Gate	IC 7404	
4.	AND Gate (Three Input)	IC 7411	
5.	Connecting Wires		As Required

## Theory

Multiplexer is a digital switch which allows digital information from several sources to be routed onto a single output line. The basic multiplexer has several data input lines and a single output line. The selection of a particular input line is controlled

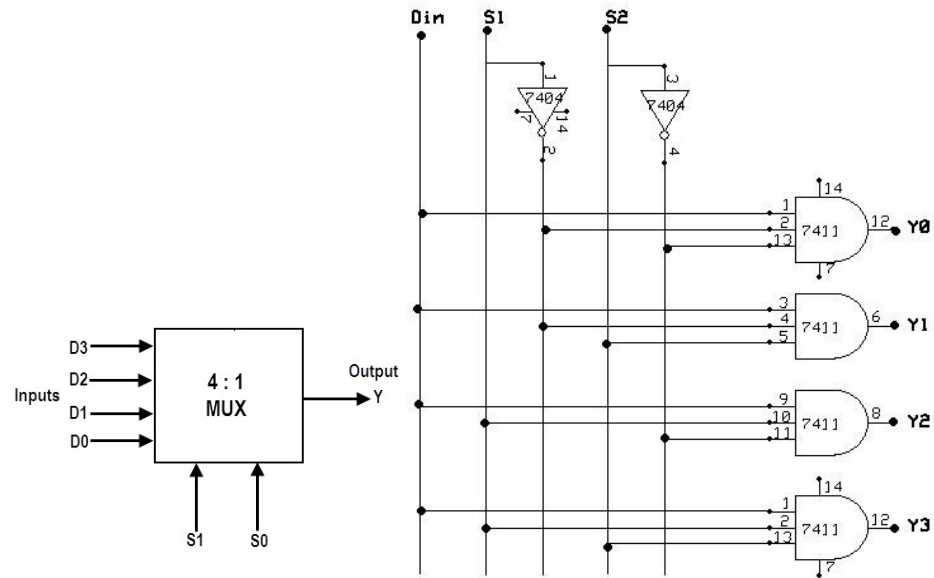
**NOTES**

by a set of selection lines. Normally, there are  $2^n$  input lines and  $n$  selector lines whose bit combinations determine which input is selected. Therefore, multiplexer is 'Many into One' and it provides the digital equivalent of an analog selector switch.

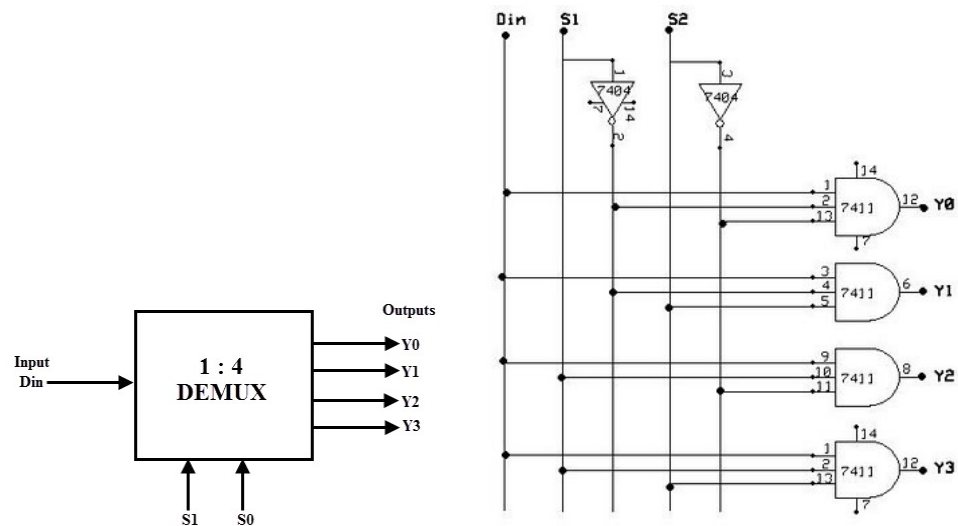
A Demultiplexer is a circuit that receives information on a single line and transmits this information on one of  $2^n$  possible output lines. The selection of specific output line is controlled by the values of  $n$  selection lines.

**Circuit Diagrams**

**1. Multiplexer ( $4 \times 1$ )**



**2. Demultiplexer ( $1 \times 4$ )**



## Procedure

1. Make the circuit connections as shown in the circuit diagrams.
2. Apply the voltage from the DC regulated power supply at the input pins of the IC according to the Truth Table.
  - (a) Apply +5V for Digital '1'
  - (b) Apply 0V for Digital '0'
3. Measure the output voltage across the output pin of the IC using multimeter.
  - (a) If the output voltage is +5V, then enter Digital '1' in the Observation Table.
  - (b) If the output voltage is 0V, then enter Digital '0' in the Observation Table.
4. Verify the output for all possible input combinations.

## NOTES

### Observation Tables

#### 1. Multiplexer ( $4 \times 1$ )

S. No	SELECTION INPUT		OUTPUT
	S1	S2	Y
1.	0	0	I <sub>0</sub>
2.	0	1	I <sub>1</sub>
3.	1	0	I <sub>2</sub>
4.	1	1	I <sub>3</sub>

#### 2. Demultiplexer ( $1 \times 4$ )

S. No	INPUT			OUTPUT			
	S1	S2	Din	Y0	Y1	Y2	Y3
1.	0	0	0	0	0	0	0
2.	0	0	1	1(Din)	0	0	0
3.	0	1	0	0	0	0	0
4.	0	1	1	0	1(Din)	0	0
5.	1	0	0	0	0	0	0
6.	1	0	1	0	0	1(Din)	0
7.	1	1	0	0	0	0	0
8.	1	1	1	0	0	0	1(Din)

### Results

Record and analyse the recorded result.

## 9. FLIP FLOP CIRCUITS USING IC.

**Aim:** To verify the characteristic table of RS, D, JK, and T Flip Flops.

### Components Required

#### NOTES

S. No	Name of the Apparatus	Range	Quantity
1.	Digital IC Trainer Kit		1
2.	NOR Gate	IC 7402	1
3.	NOT Gate	IC 7404	1
4.	AND Gate (Three Input)	IC 7411	1
5.	NAND Gate	IC 7400	1
6.	Connecting Wires		As Required

### Theory

A Flip Flop is a sequential device that samples its input signals and changes its output states only at times determined by clocking signal. Flip Flops may vary in the number of inputs they possess and the manner in which the inputs affect the binary states.

### RS Flip Flop

The clocked RS Flip Flop consists of NAND Gates and the output changes its state with respect to the input on application of Clock Pulse. When the clock pulse is HIGH, then the S and R inputs reach the second level NAND Gates in their complementary form. The Flip Flop is RESET when the R input is HIGH and S input is LOW. The Flip Flop is SET when the S input is HIGH and R input is LOW. When both the inputs are HIGH then the output is in an indeterminate state.

### D Flip Flop

To eliminate the undesirable condition of indeterminate state in the SR Flip Flop when both inputs are HIGH at the same time, in the D Flip Flop the inputs are never made equal at the same time. This is obtained by making the two inputs complement of each other.

### JK Flip Flop

The indeterminate state in the SR Flip Flop is defined in the JK Flip Flop. JK inputs behave like S and R inputs to SET and RESET the Flip Flop. The output Q is ANDed with K input and the Clock Pulse, similarly the output  $Q\bar{c}$  is ANDed with J input and the Clock Pulse. When the Clock Pulse is ZERO, then both the AND Gates are disabled and the Q and  $Q\bar{c}$  output retain their previous values. When the Clock Pulse is HIGH, then the J and K inputs reach the NOR Gates. When both the inputs are HIGH then the output toggles continuously. This is called 'Race Around Condition' and this must be avoided.

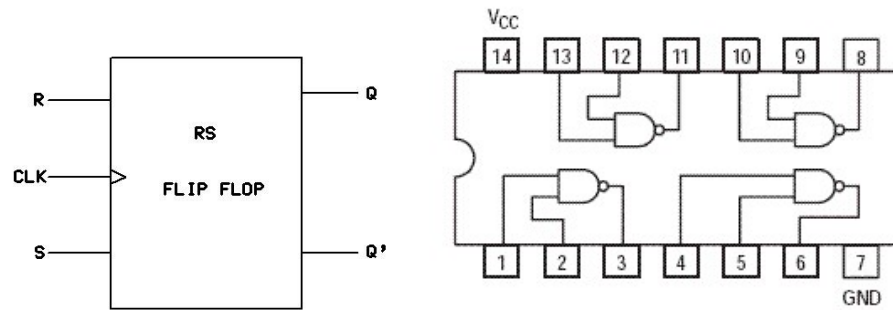
## T Flip Flop

This is a modification of JK Flip Flop, and is obtained by connecting both the J inputs and K inputs together. T Flip Flop is also called Toggle Flip Flop.

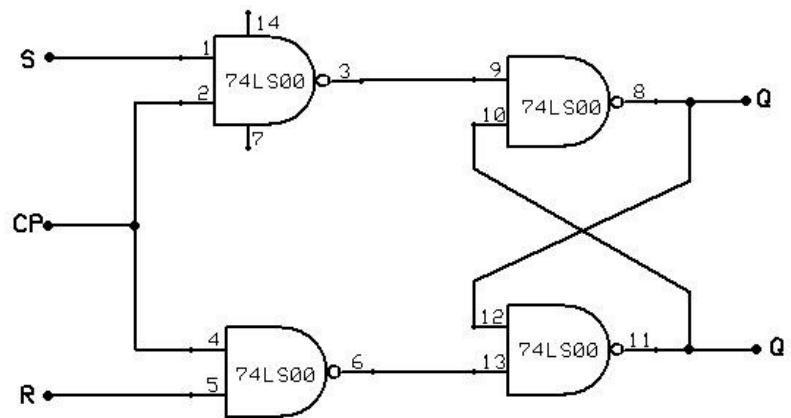
### Circuit Diagrams and Observation Tables

#### RS Flip Flop

#### Logic Symbol and Pin Configuration of 74LS00



#### Circuit Diagram of RS Flip Flop



#### Excitation Table and Characteristic Table: Truth Table

S	R	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	Invalid Inputs

## NOTES

**Characteristic Equation**

$$Q(t+1) = R'(t)Q(t) + S(t) ; S(t)R(t) = 0$$

**Excitation Table**

Q(t)	Q(t+1)	S	R
0	0	0	x
0	1	1	0
1	0	0	1
1	1	x	0

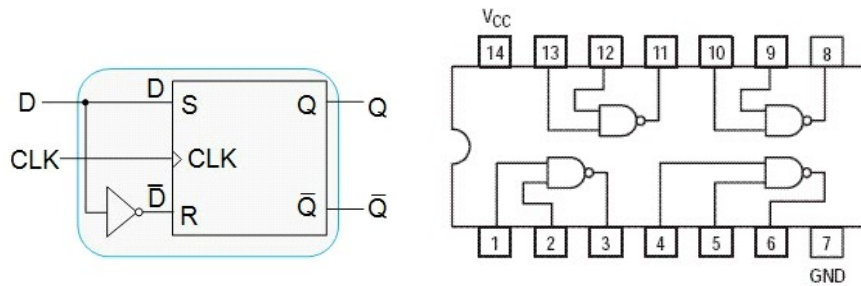
**NOTES**

**Observation Table of RS Flip Flop**

CLOCK PULSE	INPUT		PRESENT STATE (Q)	NEXT STATE (Q+1)	STATUS
	S	R			
1	0	0	0	0	
2	0	0	1	1	
3	0	1	0	0	
4	0	1	1	0	
5	1	0	0	1	
6	1	0	1	1	
7	1	1	0	X	
8	1	1	1	X	

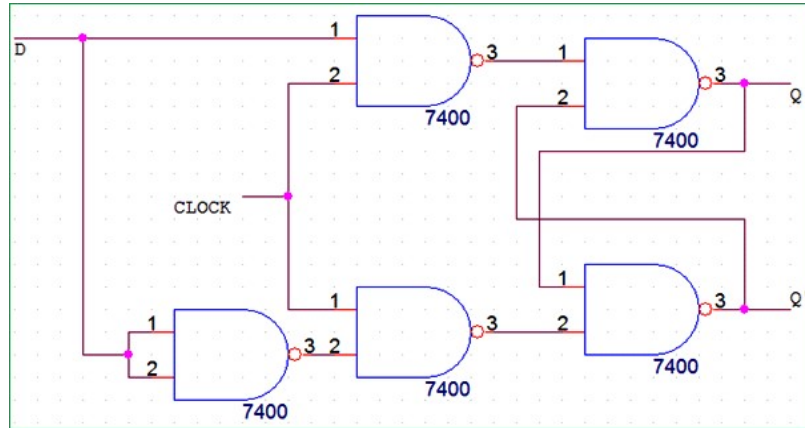
**D Flip Flop**

**Logic Symbol and Pin Configuration of 74LS00**





## Circuit Diagram of D Flip Flop



## NOTES

### Excitation Table and Characteristic Table: Truth Table

D	Q(t+1)
0	0
1	1

### Characteristic Equation

$$Q(t+1) = D(t)$$

### Excitation Table

Q(t)	Q(t+1)	D
0	0	0
0	1	1
1	0	0
1	1	1

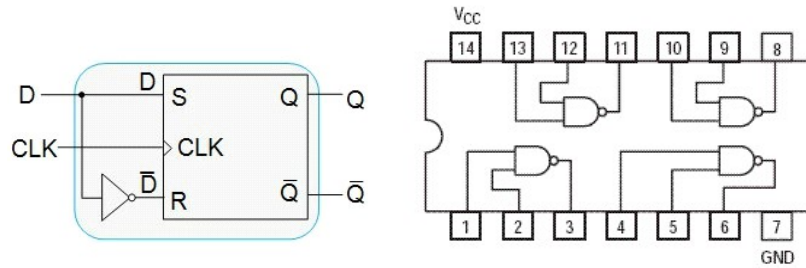
### Observation Table for D Flip Flop

CLOCK PULSE	INPUT D	PRESENT STATE (Q)	NEXT STATE (Q+1)	STATUS
1	0	0	0	
2	0	1	0	
3	1	0	1	
4	1	1	1	

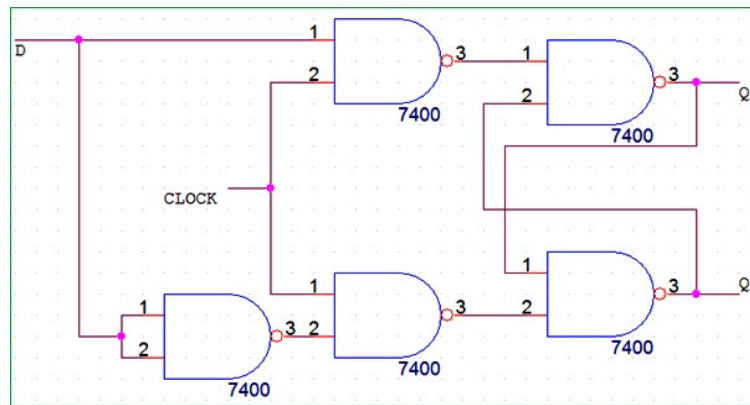
**NOTES**

**D Flip Flop**

**Logic Symbol and Pin Configuration of 74LS00**



**Circuit Diagram of D Flip Flop**



**Excitation Table and Characteristic Table: Truth Table**

D	Q(t+1)
0	0
1	1

**Characteristic Equation**

$$Q(t+1) = D(t)$$

*Excitation Table*

Q(t)	Q(t+1)	D
0	0	0
0	1	1
1	0	0
1	1	1

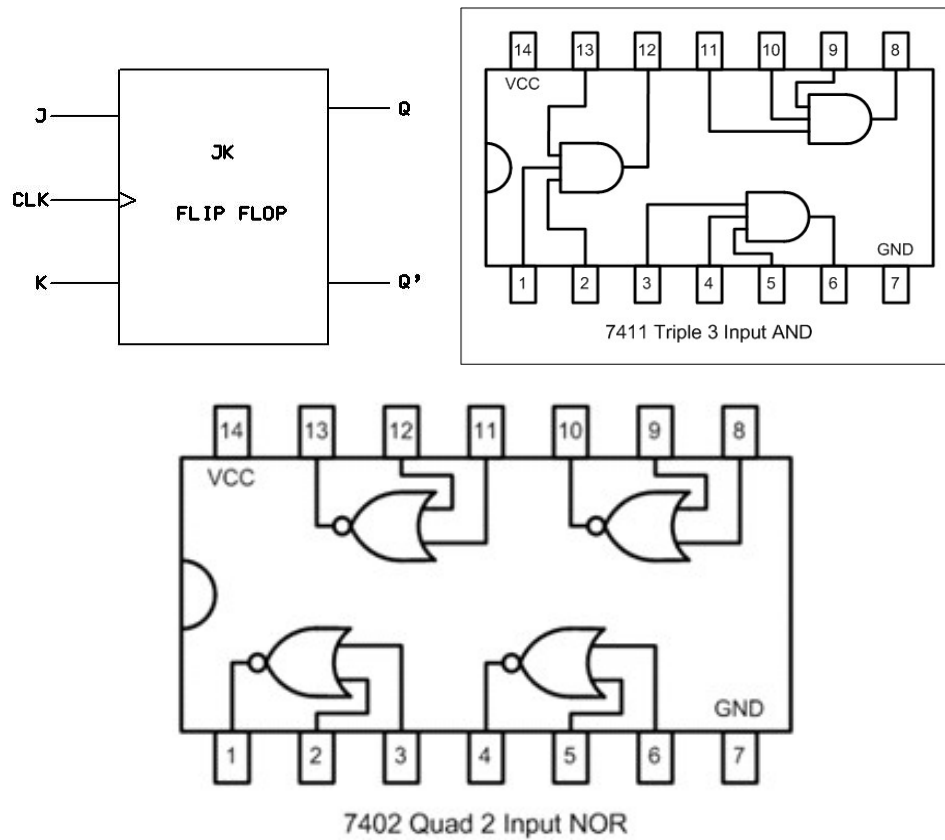
**Observation Table for D Flip Flop**

CLOCK PULSE	INPUT D	PRESENT STATE (Q)	NEXT STATE (Q+1)	STATUS
1	0	0	0	
2	0	1	0	
3	1	0	1	
4	1	1	1	

**NOTES**

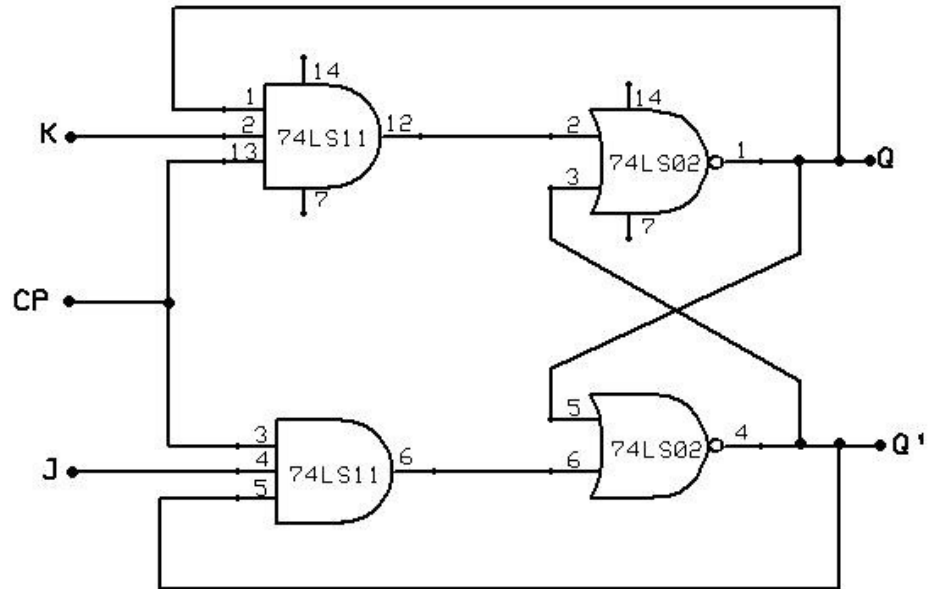
**JK Flip Flop**

**Logic Symbol and Pin Configuration of 7411, 7402**



**NOTES**

**Circuit Diagram of JK Flip Flop**



**Excitation Table and Characteristic Table: Truth Table**

J	K	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	Q'(t)

**Characteristic Equation**

$$Q(t+1) = K'(t)Q(t) + J(t)Q'(t)$$

**Excitation Table**

Q(t)	Q(t+1)	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

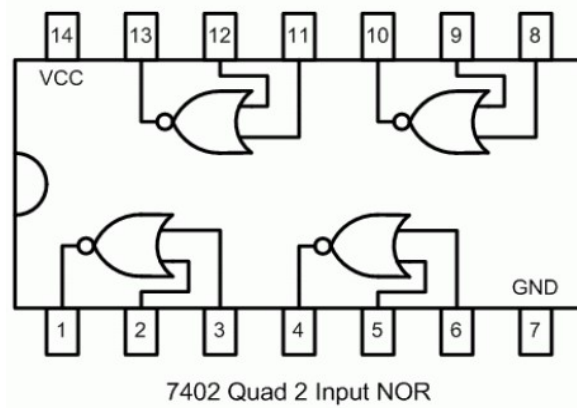
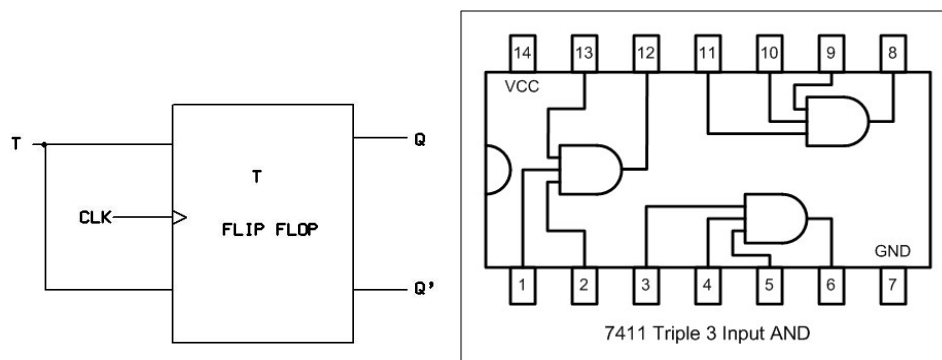
### Observation Table for JK Flip Flop

CLOCK PULSE	INPUT		PRESENT STATE (Q)	NEXT STATE (Q+1)	STATUS
	J	K			
1	0	0	0	0	
2	0	0	1	1	
3	0	1	0	0	
4	0	1	1	0	
5	1	0	0	1	
6	1	0	1	1	
7	1	1	0	1	
8	1	1	1	0	

### NOTES

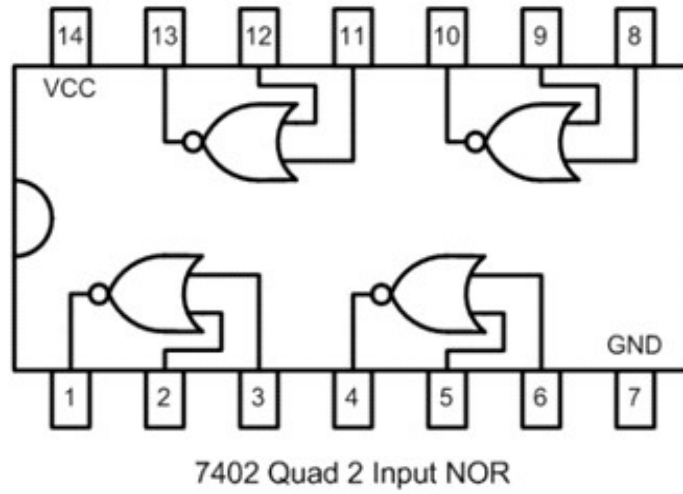
### T Flip Flop

#### Logic Symbol and Pin Configuration of 7411, 7402

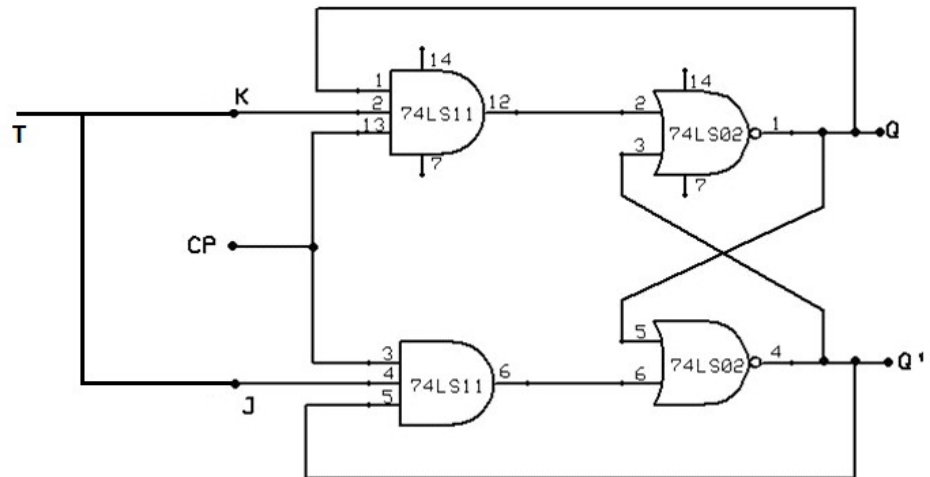


NOTES

Circuit Diagram of T Flip Flop



Circuit Diagram of T Flip Flop



Excitation Table and Characteristic Table: Truth Table

T	Q(t+1)
0	Q(t)
1	Q'(t)

Characteristic Equation

$$Q(t+1) = T'(t)Q(t) + T(t)Q'(t) = T(t) \oplus Q(t)$$

### Excitation Table

Q(t)	Q(t+1)	T
0	0	0
0	1	1
1	0	1
1	1	0

### NOTES

### Observation Table of T Flip Flop

CLOCK PULSE	INPUT T	PRESENT STATE (Q)	NEXT STATE (Q+1)	STATUS
1	0	0	0	
2	0	1	0	
3	1	0	1	
4	1	1	0	

### Procedure

1. Make the connections as per the circuit diagrams given for each type of flip flop on the breadboard.
2. Make sure to apply the biasing voltage of +5 V at PIN 14 and ground the 7th Pin of all the IC under use.
3. Apply the input to the circuit and observe the status of the output. Fill the status of the output in the Observation Table as Verified/Not Verified.

### Results

Record and analyse the recorded result.

### 10. POWDER PHOTOGRAPH - X-RAY METHOD

**Aim:** To study the Crystalline Structure of any given Crystalline sample of material by producing the Powder Photograph on X-Ray Film.

In this experiment, the diffraction patterns of X-rays of known wavelengths will be analysed to determine the lattice constant for the diffracting crystal of Sodium Chloride (NaCl).

### Components Required

1. X-Ray Tube
2. Ni or Zr Filter
3. Collimator

4. Crystalline Sample of Material
5. Screen (X-Ray Film)
6. Crystals of Sodium Chloride (NaCl)

## NOTES

### Theory

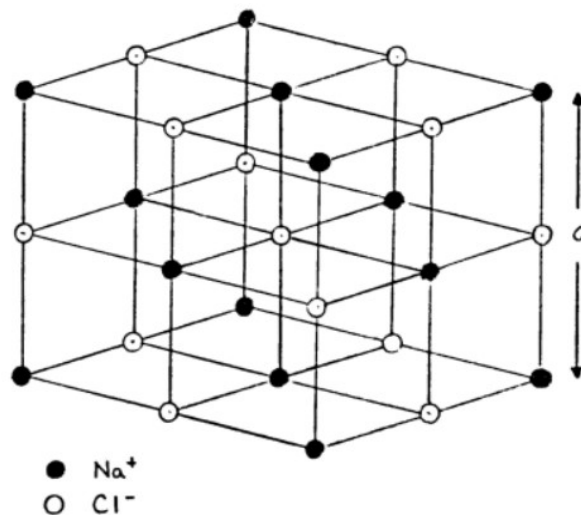
In 1912, Max von Laue, a German physicist, discovered that X-rays could be diffracted, or scattered, in an orderly way by the orderly array of atoms in a crystal, i.e., the crystals can be used as three-dimensional 'Diffraction Gratings' for X-rays. The phenomenon of X-ray diffraction from crystals is used both to analyse X-rays of unknown wavelength using a crystal whose atomic structure is known, and to determine, using X-rays of known wavelength, the atomic structure of crystals.

Basically there are following two main ways of studying metals and alloys:

1. **Metallography:** In this procedure 'Polished' and 'Etched' surfaces of sample are examined.
2. **Cooling Curves:** Here discontinuities are studied which indicate some sort of phase change.

Method of X-ray diffraction which is a part of Metallography has been proved to be a much clearer, simpler and more objective way of investigation. This is done using Debye-Scherrer method (X-ray).

The atomic structure of crystals is deduced from the directions and intensities of the diffracted X-ray beams. A crystal is built of 'Unit Cells' repeated regularly in three dimensions. The directions of diffracted X-rays depend on the repeat distances of the unit cells. The strengths of the diffracted beams depend on the arrangement of atoms in each unit cell. Figure 1 given below shows the arrangement of  $\text{Na}^+$  and  $\text{Cl}^-$  ions in a unit cell of NaCl.



**Fig. 1** Arrangement of  $\text{Na}^+$  and  $\text{Cl}^-$  Ions in a Unit Cell of NaCl



One method of interpreting X-ray diffraction is the Bragg formulation. The X-ray waves are considered as being reflected by sheets of atoms in the crystal. When a beam of monochromatic (uniform wavelength) X-rays strikes a crystal, then the wavelets scattered by the atoms in each sheet combine to form a reflected wave. If the path difference for waves reflected by successive sheets is a whole number of wavelengths, the wave trains will combine to produce a strong reflected beam.

NOTES

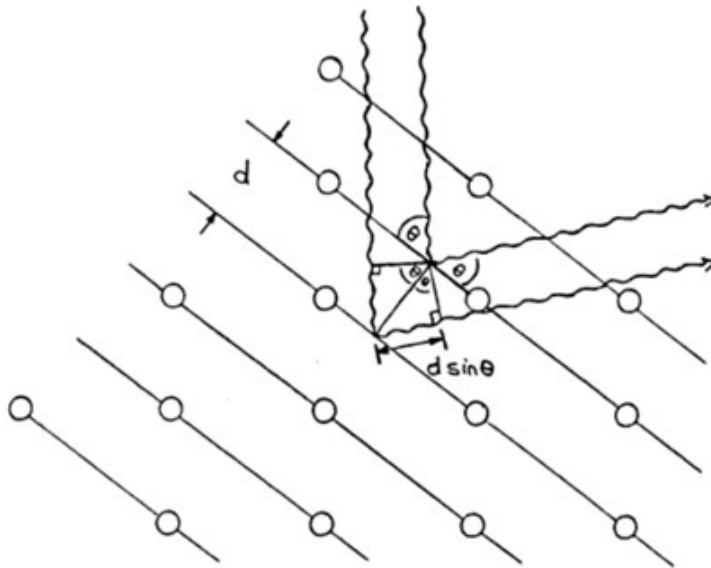


Fig. 2

The Figure 2 illustrates that if the spacing between reflecting planes is  $d$  and the glancing angle of the incident X-ray beam is  $\theta$ , then the path difference for waves reflected by successive planes is  $2d \sin \theta$ . Hence the condition for diffraction as per the Bragg condition is,

$$n\lambda = 2d \sin \theta \quad \dots(1)$$

Where,

$n$  = An integer, the diffraction order

$\lambda$  = X-ray wavelength

$d$  = Lattice plane spacing

$\theta$  = Bragg angle relative to the primary ray

Debye-Scherrer method is based on refraction of X-ray and is used to determine the physical dimensions of the unit cell of crystallized materials. A powdery crystalline sample is exposed to the monochromatic X-rays. The powder sample contains minute mono-crystals of about 5 - 50  $\mu\text{m}$  diameter. Diffracted X-rays are recorded on a strip of film wrapped around the circumference of the camera. The angular position of the diffracted X-rays recorded on the film gives structural information about the sample.

## NOTES

### Debye-Scherrer Photographs

For taking a Debye-Scherrer photograph, a powdery crystalline sample is trans-illuminated with monochromatic X-rays. The interference pattern of the scattered radiation is frozen on an X-ray film. The powder sample contains minute mono-crystals of about 5–50 nm diameter, the so called crystallites. A set of lattice planes in a crystallite leads to a diffraction reflection on the X-ray film if it is aligned so that the Bragg condition,  $n\lambda = 2d \sin \theta$ , is fulfilled.

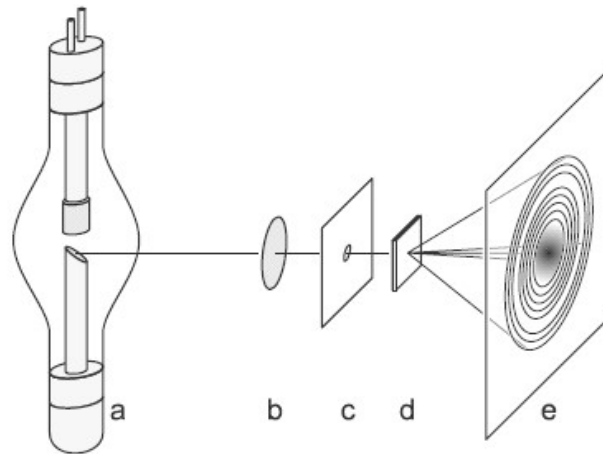
The angle between the diffraction reflection and the film, which is aligned perpendicularly to the primary ray, is  $2\theta$ .

#### Procedure

1. Set up the experiment as shown below in Figure 3.

Where,

a = X-ray tube, b = Zr filter, c = Collimator, d = Sample, e = X-ray Film



*Fig. 3 Experiment Setup*

2. In general the crystallites are randomly oriented without any privileged direction so that there are always some crystallites in the crystal powder which correspond to a rotation of the crystallite under consideration around the primary axis. In the arrangement of the film selected here, their diffraction reflections form a circle on the X-ray film with the radius,

$$R = L \cdot \tan 2\theta \quad \dots(2)$$

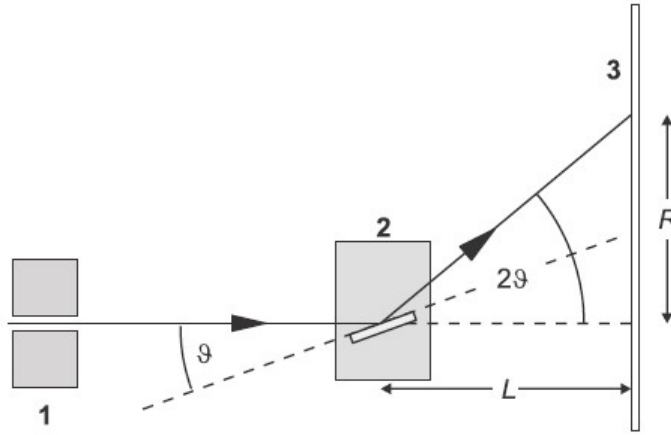
L = Distance between the sample and the film

3. The finer the power is, the more uniformly the individual reflections of the crystallites will be lined up to form a circle. The complete diffraction pattern is a set of concentric circles.

Because of Equations (1) and (2), each radius R corresponds to a certain lattice plane spacing d and a certain diffraction order n or, more precisely, a certain ratio,

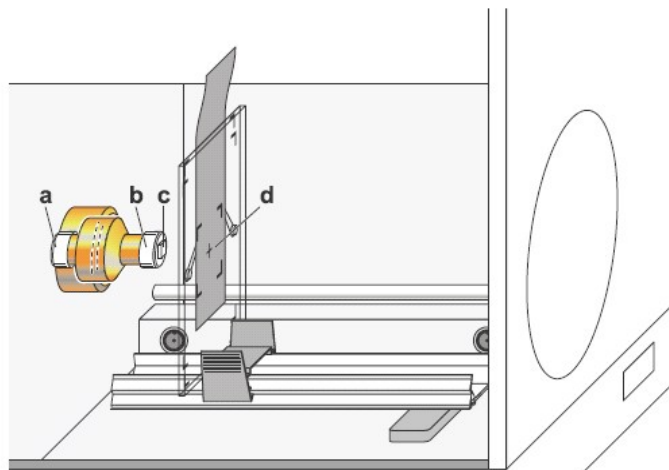
$$d' = d/n$$

4. Figure 4 illustrates the Bragg reflection at an ‘appropriate’ set of lattice planes of a particular crystallite in the powder sample. In the experiment,  
1 = Collimator, 2 = Set of lattice planes, 3 = Film



*Fig. 4 Bragg Reflection*

5. In this experiment, Debye-Scherrer photographs of crystals with NaCl structure are taken. The Bragg angles are obtained according to Equation (2) from the radii  $R$  of the diffraction rings and the distance  $L$  between the sample and the film. For the evaluation, the associated values of  $\sin 2\theta$  are decomposed into a constant factor and the smallest integer. Figure 5 illustrates the experimental setup for taking a Debye-Scherrer photograph of polycrystalline powder samples.
6. The experimental setup is illustrated in Figure 5.
- If necessary, remove the goniometer or the plate capacitor X-ray.
  - Dismount the collimator, mount the Zr filter (a) (from the scope of supply of the X-ray apparatus) on the ray entrance side of the collimator and re-insert the collimator.



*Fig. 5 Experimental Setup for taking a Debye-Scherrer Photograph*

## NOTES

## NOTES

### Debye-Scherrer Photograph of NaCl

- Carefully grind the dry NaCl salt in the mortar, and embed an approximately 0.4 mm thick layer between two pieces of transparent adhesive tape.
- Carefully attach the sample (c) to the pinhole diaphragm (b) with adhesive tape (from the scope of supply of the film holder X-ray), and put the pinhole diaphragm onto the collimator.
- Clamp the X-ray film (d) at the film holder so that it is centred on the marked area, and see to it that the entire surface of the film is planar.
- Clamp the film holder onto the experiment rail, and mount the experiment rail in the experiment chamber of the X-ray apparatus.
- Make a 13 mm long spacer from paper board and shift the film holder so that the distance between the sample and the film is 13 mm (by varying the distance between the sample and the film the area covered in the photograph is changed).
- Set the tube high voltage  $U = 35$  kV, the emission current  $I = 1.0$  mA and  $Db \Delta\beta = 0.0$ .
- Select the measuring time  $\Delta t = 14400$  s, and start the exposure timer with the key Scan. If the exposure time is longer, the reflections near the centre are blurred by the un-scattered X-rays, however structures which are farer away from the centre become discernable.
- When the exposure time is over, take the film holder with the experiment rail out of the experiment chamber.
- Remove the X-ray film from the holder, and develop it according to the instruction sheet for the X-ray film.

### Results

Record your observations and analyse.

## 11. RESISTIVITY MEASUREMENTS OF THIN FILMS.

**Aim:** To measure the sheet Resistance (Surface Resistance) of given Metallic Piece.

### Theory

All conductive or nonconductive materials have their lateral surface resistance to electricity. Further to elaborate it can be said that Sheet resistance (also known as surface resistance or surface resistivity) is a common electrical property used to characterize thin films of conducting and semiconducting materials. Based on their resistivity, materials can be characterized by measuring the amount of resistance to electricity.

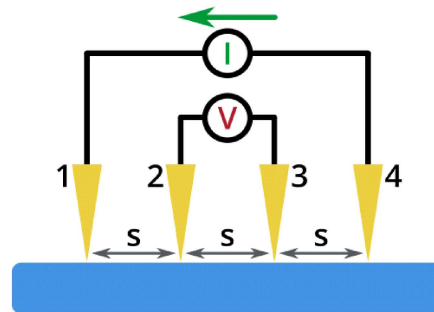
Sheet Resistance ( $R_s$ ) is commonly defined as the Resistivity ( $\rho$ ) of a material divided by its Cross Section ( $t$ ):

$$R_s = \frac{\rho}{t}$$

According to Ohm's law for electrical circuit theory, the resistance of a material is the applied voltage divided by the current drawn across the material between two electrodes (two specific points) which can be further defined by formulae  $R = V/I$

Where:  $R$ =Resistance (measured in ohms,  $\Omega$ ),  $V$ = Voltage (measured in volts,  $V$ ),  $I$ = Current (measured in amperes,  $A$ )

Using a thin film of a square metallic piece, i.e., the resistance between opposite sides of a square directly using a four-point probe method also known as Kelvin technique. A four-point probe consists of four electrical probes in a line, with equal spacing between each of the probes as shown in Figure 1.



*Fig. 1 A Schematic Diagram of a Four-Point Probe*

The four probes have equal spacing ( $S$ ) and are shown in contact with a surface. A current ( $I$ ) is injected through Probe 1 and collected through Probe 4, whilst the voltage is measured between Probes 2 and 3.

It operates by applying a Current ( $I$ ) on the outer two probes and measuring the resultant voltage drop between the inner two probes. The sheet resistance can then be calculated using the equation below:

$$R_s = \frac{\pi}{\ln(2)} \frac{\Delta V}{I} = 4.53236 \frac{\Delta V}{I}$$

The material being tested should not be thicker than 40% of the spacing between the probes, and the size of the sample should be sufficiently large.

**Procedure**

1. Place the sample on the stage, in the center under the four-point probe head.
2. Raise the stage until the probes are in good contact with the sample. As the probes are spring-loaded, they will compress as the sample is raised into them - creating a constant contact force.
3. Set the appropriate range on the Source-Measure Unit (SMU).
  - (a) For this you will need to estimate the order of magnitude of the sample. The lower the resistance, the lower the required range number.

**NOTES**

NOTES

(b) If you do not know what resistances are likely, start with range 1 (up to 100 mA current) and move up the ranges if the target current cannot be achieved.

(c) Ensure that the same range is set physically on the system as is selected in the software.

4. You have to set the settings in the practical software. The question mark buttons next to each setting give details about the settings.
5. Click the 'Measure' button.
6. The system will then try to apply the set target current between the outer two probes. Once this has been achieved, the voltage will be measured between the inner two probes and the sheet resistance calculated from these values.
7. Once the measurement has finished, the average sheet resistance will be displayed in the results box on the right side of the window.

The resistivity and conductivity will also be displayed if the sample thickness was provided. The observations are recorded in the table.

**Observations**

The observations are recorded in the following table.

Current I = 100 mA (Constant)

Sr. No.	Temperature (°C)	Voltage (volts)	Temperature (°K)	$\rho$ (ohm.cm.)	$10^5/T$	$\text{Log}_{10}\rho$
1	17					
2	20					
3	30					
4	40					
5	50					
6	60					
7	70					
8	80					
9	90					
10	100					
11	110					
12	120					
13	130					
14	140					
15	150					

**Result**

The band gap of given semiconductor is found to be = eV.

## 12. HALL EFFECT - MOBILITY AND HALL CONSTANT DETERMINATION.

**Aim:** The aim of this experiment is,

- To determine the Hall Voltage developed across the sample material.
- To calculate the Hall Coefficient and the Carrier Concentration of the sample material.

### Components Required

Two Solenoids, Constant Current Supply, Four Probes, Digital Gauss Meter, Hall Effect Apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

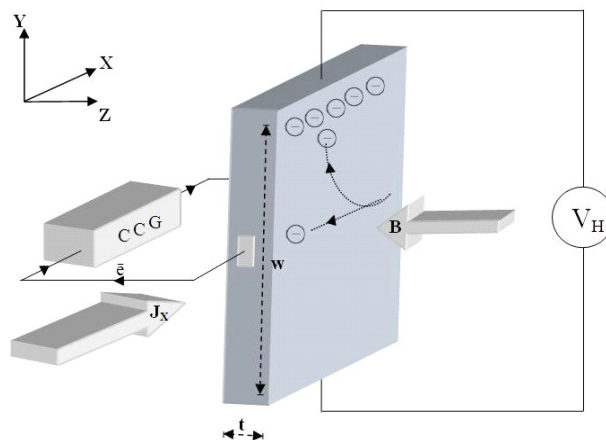
### Theory

In 1879 E. H. Hall observed that when an electrical current passes through a sample placed in a magnetic field, a potential proportional to the current and to the magnetic field is developed across the material in a direction perpendicular to both the current and to the magnetic field. If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall Effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness  $t$  kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current  $I$  flow through the sample. If  $w$  is the width of the sample and  $t$  is the thickness. There for current density is given by,

$$J_x = \frac{I}{wt} \quad \dots(1)$$

Figure 1 illustrates the schematic representation of Hall Effect in a conductor. Where, CCG – Constant Current Generator,  $J_x$  – Current Density,  $\bar{e}$  – Electron,  $B$  – Applied Magnetic Field,  $t$  – Thickness,  $w$  – Width and  $V_H$  – Hall Voltage.



**Fig.1** Schematic Representation of Hall Effect in a Conductor

### NOTES

## NOTES

If the magnetic field is applied along negative Z-axis, the Lorentz force moves the charge carriers (say electrons) toward the Y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field  $E_y$  in the sample. This develop a potential difference along Y-axis is known as Hall Voltage  $V_H$  and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a voltmeter. When the applied magnetic field  $\mathbf{B} = 0$ , then the voltage difference will be zero.

We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward.

In both cases, under the application of magnetic field the magnetic Lorentz force,  $F_m = q(\mathbf{v} \times \mathbf{B})$  causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically, we can express it as,

$$eE = evB \quad \dots(2)$$

Where ' $e$ ' the Electric Charge, ' $E$ ' the Hall Electric Field developed, ' $B$ ' the Applied Magnetic Field and ' $v$ ' is the Drift Velocity of Charge Carriers.

And the current ' $I$ ' can be expressed as,

$$I = neAv \quad \dots(3)$$

Where ' $n$ ' is the Number Density of Electrons in the Conductor of Length  $l$ , Breadth ' $w$ ' and thickness ' $t$ '.

Using Equations (1) and (2) the Hall Voltage  $V_H$  can be written as,

$$V_H = Ew = vBw = \frac{IB}{net} \quad \dots(4)$$

By rearranging Equation (4) we get,

$$R_H = \frac{V_H \times t}{I \times B} \quad \dots(5)$$

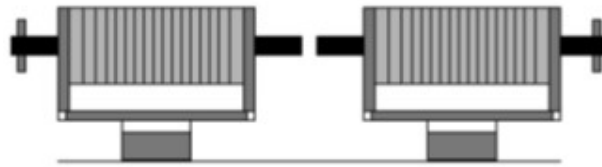
Where  $R_H$  is called the **Hall Coefficient**.

$$R_H = 1/ne \quad \dots(6)$$

### Circuit Diagram

Figure 2 illustrates the two electromagnets. The Hall Probe is placed between two of them.





**Fig. 2** Two Electromagnets

**NOTES**

**Procedure**

1. Connect 'Constant Current Source' to the solenoids.
2. Four probe is connected to the Gauss Meter and placed at the middle of the two solenoids.
3. Switch ON the Gauss Meter and Constant Current Source.
4. Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss Meter readings.
5. Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
6. Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator (CCG) and connect red wires to milli voltmeter in the Hall Effect apparatus.
7. Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids.
8. Switch ON the constant current source and CCG.
9. Carefully increase the Current  $I$  from CCG and measure the corresponding Hall Voltage  $V_H$ . Repeat this step for different Magnetic Field  $B$ .
10. Thickness  $t$  of the sample is measured using screw gauge.
11. Hence calculate the Hall Coefficient  $R_H$  using the Equation (5).
12. Then calculate the Carrier Concentration  $n$  using Equation (6).

**Observation Table**

Trial No:	Magnetic Field (Tesla T)	Thickness (t) m	Hall Current, mA	Hall Voltage mV	$R_H$
1					
2					
3					
4					
5					

.....

**Results**

Hall Coefficient of the Material = .....

Carrier Concentration of the Material =..... m<sup>-3</sup>

**NOTES**

**13. DIELECTRIC CONSTANT - MICROWAVE FREQUENCY USING KLYSTRON**

**Aim:** To determine the Dielectric Constant of Microwave Frequency using Klystron.

**Theory**

The Dielectric Constant **k** is the relative **permittivity** of a **dielectric** material. It is an important parameter in characterizing capacitors. It is unfortunate that the same symbol **k** is often used for Coulomb’s constant, so one must be careful of this possible confusion.

Dielectric Constant, property of an electrical insulating material (a **dielectric**) equal to the ratio of the capacitance of a capacitor filled with the given material to the capacitance of an identical capacitor in a vacuum without the **dielectric** material.

The dielectric constant is the ratio of the permittivity of a substance to the permittivity of free space. It is an expression of the extent to which a material concentrates electric flux, and is the electrical equivalent of relative magnetic permeability.

As the dielectric constant increases, the electric flux density increases, if all other factors remain unchanged. This enables objects of a given size, such as sets of metal plates, to hold their electric charge for long periods of time, and/or to hold large quantities of charge. Materials with high dielectric constants are useful in the manufacture of high-value capacitors.

How effective a dielectric is at allowing a capacitor to store more charge depends on the material the dielectric is made from. Every material has a dielectric constant  $\epsilon$ . This is the ratio of the field without the dielectric ( $E_0$ ) to the Net Field ( $E$ ) with the Dielectric:

$$\kappa = E_0/E$$

$E$  is always less than or equal to  $E_0$ , so the dielectric constant is greater than or equal to 1. The larger the dielectric constant, the more charge can be stored.

Completely filling the space between capacitor plates with a dielectric increases the capacitance by a factor of the dielectric constant:

$$C = \kappa C_0, \text{ where } C_0 \text{ is the capacitance with no dielectric between the plates.}$$

For a parallel-plate capacitor containing a dielectric that completely fills the space between the plates, the capacitance is given by:

$$C = \kappa \epsilon_0 A/d$$

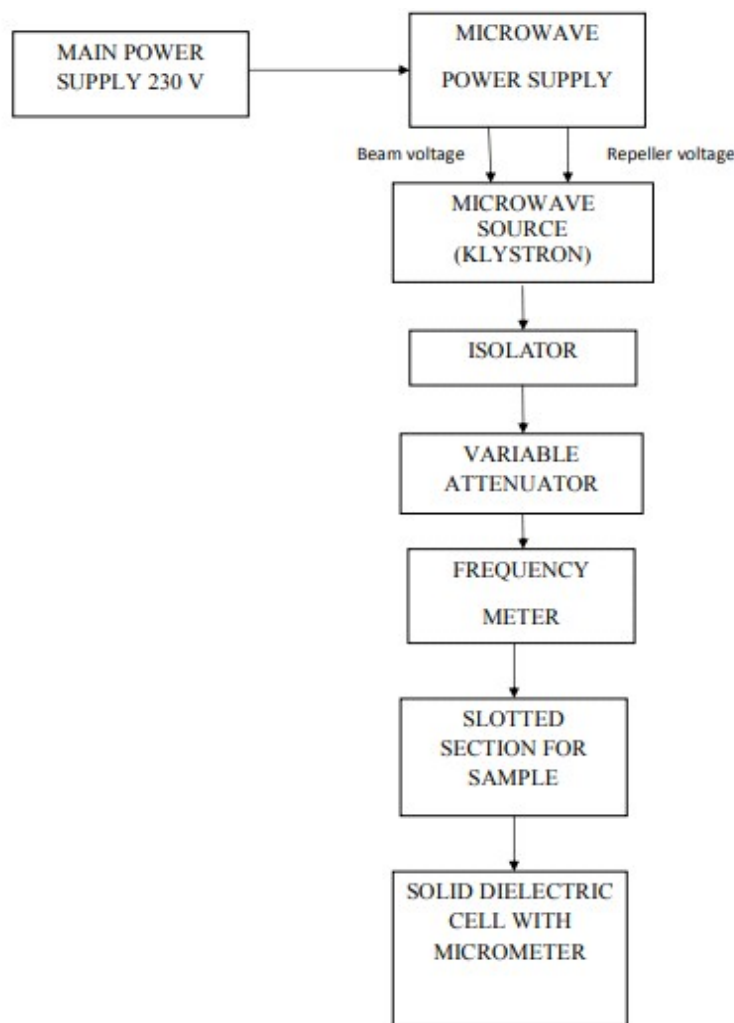
The capacitance is maximized if the dielectric constant is maximized, and the capacitor plates have large area and are placed as close together as possible.

If a metal was used for the dielectric instead of an insulator the field inside the metal would be zero, corresponding to an infinite dielectric constant. The dielectric usually fills the entire space between the capacitor plates, however, and if a metal did that it would short out the capacitor - that's why insulators are used instead.

### Materials Required

Capacitor plates, Metal, Power supply, Klystron, Isolator, Variable Attenuator, Frequency meter, Solid Dielectric cell.

### Circuit Diagram



*Fig. 1 Block Diagram for Measurement of Dielectric Properties*

Figure 1 illustrates the block diagram used to measure the Dielectric properties.

## NOTES

NOTES

**Procedure**

1. Connect the power supply, Klystron, isolator, variable attenuator, frequency meter, slotted section with the collected sample and solid dielectric cell as shown in the block diagram in Figure 1.
2. The microwave power source was energised and suitable power level in the indicating meter was noted when empty sample holder (container) had been placed inside slotted section.
3. The position of standing wave voltage minima was read and recorded and  $g$  was computed by the double minima method.
4. Frequency of the wave was measured by frequency meter.
5. With probe positioned at the maximum of the standing wave pattern, the cell was filled with the sample under test by taking out the shorting plunger. The plunger was installed in the cell and moved through the dielectric till it touches the dielectric cell.
6. The plunger was slowly moved up and the minima was recorded.
7. The plunger was moved down till the meter reads double of that in Step 5 and the plunger position was recorded.
8. The plunger was moved up and when it was positioned on the second minima, the position of the minima and double the minima width were measured and recorded.
9. The procedure was repeated for various samples collected at different temperatures.
10. Reflex klystrons are widely used in laboratory measurements, whose frequency range is 1 to 25 GHz.

Record the readings at ambient temperature, say  $32^{\circ}\text{C}$  by above procedure. Remember that the Beam voltage, Repeller voltage, first and second minima of empty waveguides will be constant.

Record the observations for future computation.

**Observation Table**

Material	Dielectric Constant	Dielectric Strength (kV/mm)

**Results:** Evaluate the readings to obtain the final conclusion.

## 14. DETERMINATION OF CURIE POINT - FERROMAGNETIC MATERIAL.

**Aim:** To determine the Curie Point of given Magnetic Material.

### Theory

On heating, some 'Magnetic Metals' experience some changes in their magnetic properties at high temperature, in the heating process, beyond certain temperature the metals lose their magnetic properties this phase is known as Curie Point, also called Curie Temperature.

This phenomena was first discovered by one French Physicist Mr Pierre Curie in 1895. He discovered that below the Curie point, atoms in the molecular structure of iron, have the behaviour of tiny magnets which remain aligned to each other in same direction hence their magnetic field reinforces each other and the metal remains ferromagnetic.

Further to the studies it has been revealed that heating of magnetic metals start loosing magnetism and on heating beyond their curie point, the same atomic magnets alternate in opposite direction, cancelling the magnetic fields of each other, loose their magnetic property and become antiferromagnetic. It is also revealed that on cooling the metals, the process is reversed and they regain their magnetic property at low temperature. The Curie Temperature of Iron is about 1043 K.

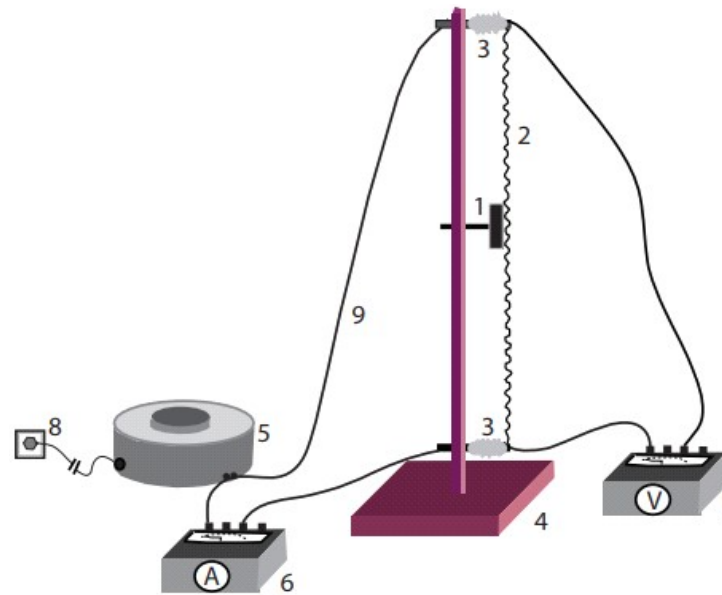
This experiment is based on a well-known qualitative demonstration of Curie temperature. A long ferromagnetic wire, in the form of a spiral, is attracted to a strong permanent magnet placed near its midpoint, as shown in Figure 1 given below. The temperature of the wire is increased by passing a current through it. When the temperature reaches the Curie point, the wire becomes paramagnetic and is no longer strongly attracted to the magnet. This is a quantitative experiment which provide an accurate way to determine the temperature at which the ferromagnetic-paramagnetic transition occurs.

### Procedure

1. Set up the experiment as shown in Figure 1 to find the Curie point.
2. It is composed of a ferromagnetic material (Kanthal Type D)<sup>2</sup> in the form of the spiral-heating element stretched vertically between insulating clamps mounted on the support stand.
3. A permanent magnet is mounted near the middle of the support stand such that it visibly attracts the hanging spiral. The spiral is connected to the output of the auto-transformer (Variac).
4. The current through the wire is measured with the Ammeter (A), and the potential difference across it with the Voltmeter (V).

### NOTES

## NOTES



**Fig. 1** Set Up for Experiment

Electrical energy  $W$  is delivered to the wire at a constant rate,

$$P = VI$$

Where  $V$  and  $I$  are, respectively, the potential difference across the spiral and the current flowing through it. We may therefore write:

$$W = VI t$$

Where ' $t$ ' is the amount of time the current has flowed. A portion of this energy increases the internal energy of the spiral, and another portion is radiated into the surrounding environment. If a spiral of mass  $m$  and specific heat  $c$  is heated from an initial temperature  $T_0$  to a higher temperature  $T$ , then the change in the internal energy of the spiral is expressed by:

$$\Delta E_t = mc(T - T_0)$$

5. The energy balance equation for the spiral wire is:

$$W = \Delta E_t + E_p$$

$$\text{or } VI t = \Delta E_t + E_p$$

6. In this experiment, the voltage is set to the minimum level at which the heated spiral stops being attracted by the permanent magnet, hence the spiral loses its ferromagnetic properties and becomes a paramagnetic material. The temperature of the spiral at that point is the desired Curie Temperature  $T_c$ . After the spiral reaches a constant temperature, the  $\Delta E_t$  term is equal to zero.

### Results and Conclusions

The following table gives typical data obtained for two different spiral wires.

Properties of Spiral Wires	Spiral "a"	Spiral "b"
Diameter ( $d$ )	$0.60 \pm 0.01$ mm	$0.62 \pm 0.01$ mm
Length ( $l$ )	$10400 \pm 1$ mm	$7875 \pm 1$ mm
Surface area ( $S = \pi dl$ )	$196 \pm 4$ cm <sup>2</sup>	$148 \pm 3$ cm <sup>2</sup>
Emissivity ( $e$ ) (Refs. 2, 4)	0.70	0.70
Voltage at Curie temperature ( $V$ )	$147 \pm 1$ V	$108 \pm 1$ V
Current at Curie temperature ( $I$ )	$2.99 \pm 0.01$ A	$2.92 \pm 0.01$ A
Nominal Curie Temperature ( $T_C$ ) (Refs. 2, 4)	600°C	600°C

We can calculate the Curie Temperature  $T_C$  for the two wires as follows:

$$\text{Spiral a: } TC = 858 \text{ K} \pm 6\text{K} = 581 \pm 6^\circ\text{C}$$

$$\text{Spiral b: } TC = 869 \text{ K} \pm 6\text{K} = 596 \pm 6^\circ\text{C}$$

## 15. SUSCEPTIBILITY BY GOUY'S METHOD

**Aim:** To determine the magnetic susceptibility of a paramagnetic sample by measuring the force exerted on the sample by a magnetic field gradient using the Gouy's method.

### Theory

Magnetic susceptibility  $\chi$  is a quality unique to each material (much like conductivity and resistivity) and is defined as the ratio of the magnetization of the material to the applied magnetic field. For small magnetic fields:

$$\bar{M} = \chi \bar{H}$$

Where  $\bar{M}$  is the magnetization and  $\bar{H}$  is the magnetic field.

Materials may be split into one of three magnetic classes, diamagnetic materials, paramagnetic materials and ferromagnetic materials. In diamagnetic materials, like water, the magnetic effects of spin and orbital motion cancel each other out. Small dipole moments can be induced by an external field. Thus, diamagnetic materials are weakly repelled by a regular magnet.

Paramagnetic materials, like aluminum, have permanent magnetic dipole moments in each particle. They are weakly attracted to an ordinary magnet. Ferromagnetic materials greatly strengthen the magnetic field and are strongly attracted to an ordinary magnet.

It is easy to deduce that the ferromagnetic materials produce a much bigger force and change in the magnetic field than those of the other two categories. In this experiment, you will be working with diamagnetic and paramagnetic substances.

## NOTES

NOTES

One simple way to experimentally determine the magnetic susceptibility of a specific material is the Gouy method. The method determines the force exerted on a sample through a change in mass, and uses that value to find the susceptibility. In this experiment, you will determine the magnetic susceptibility of a number of materials by using a sample, a magnetic field, and a mass balance, and compare the values to the known material susceptibilities.

For diamagnetic materials, let us imagine that an atom that is a nucleus in a stationary cloud of electrons is placed in a magnetic field, as shown in Figure 1(a). When the field increases, a torque is exerted on the charges. As a result, the charges circulate in the direction as shown in Figure 1(b). A circulating current is therefore set up in a direction opposite to the electron flow as shown in Figure 1(c). This current produces a magnetic field in a direction opposite to the applied field, and so the substance is repelled by the magnetic field.

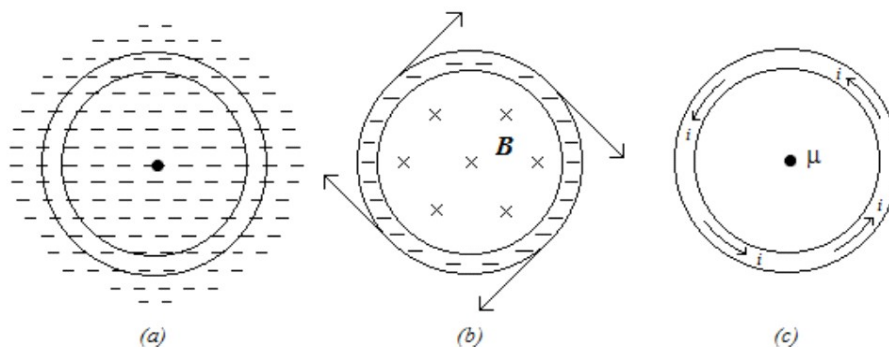


Fig. 1 The Origin of Diamagnetism

Figure 1 illustrates the origin of diamagnetism, where (a) represents the electron cloud, (b) the current induced by a varying magnetic field into the plane of the paper, and (c) the magnetic field caused by this current (opposite to the inducing field).

All atoms behave this way, but because the repulsion is so weak, the only materials that exhibit diamagnetic effects are those with very weak atomic magnetic moments. For materials with their own permanent magnetic dipole moments, other effects are strong enough to outweigh repulsion. If we lower a sample of a substance into a region of magnetic field between two poles, a force will be produced. The Gouy balance measures this force as an apparent change of mass of a sample. Using a simple mass balance, two measurements are taken,  $m_0$  (the initial mass reading) and  $m_f$  (the final mass reading after lowering the sample into the field).

The force is thus given by:

$$\vec{F} = \Delta m \vec{g} = (m_f - m_0) \vec{g}$$

Where  $g$  is the acceleration due to gravity (about  $9.8 \text{ m/s}^2$ ).



We now derive an expression for the force applied by the magnet on the sample. A substance's magnetic permeability  $\mu$  is given by,

$$\mu = \mu_0 (1 + \chi)$$

Where  $\mu_0$  is the permeability of free space or the magnetic constant ( $4\pi \times 10^{-7} \text{ N/A}^2$ ) and  $\chi$  is the magnetic susceptibility.

Assume that  $\chi_m$  is the magnetic susceptibility. Which for small magnetic fields is defined as,

$$\chi_m = \frac{M}{H}$$

Where  $M$  is the magnetization.

When a magnetic field,  $B$ , is applied the energy changes by an amount,

$$E = -m_\mu \cdot B = -VM \cdot B$$

Where  $V$  is the volume of the sample.

If there is a gradient in the magnetic field along the  $z$  direction, then the sample experiences a force per unit volume given by assuming  $m$  is uniform throughout the sample,

$$f = \frac{dU}{dz} = \frac{\mu_0 \chi_m}{2} \frac{d}{dz} (H^2) \quad \dots(1)$$

### Equipment/Materials Required

The Gouy balance, Powder specimen ( $\text{FeCl}_2$  or  $\text{Fe}_2\text{SO}_4$ ) in a Glass Tube, DC Power Supply for the Magnet.

### Procedure

1. The electromagnet is energized by a DC power supply.
2. The variable magnetic field is provided by the wedge-shaped pole-pieces. The entire electromagnet is housed inside a wooden casing.
3. The distance between the pole-pieces can be varied by means of a handle on top of the wooden casing.
4. A digital balance is placed which carries a hook at the bottom for suspending the glass tube containing the material ( $\text{FeCl}_2$ , or  $\text{Fe}_2\text{SO}_4$ ).
5. The magnetic field between the pole pieces can be varied by changing the current through the coils using a DC power supply.
6. The magnetic field corresponding to the current through the coils can be determined using a Gauss meter.
7. Zero-adjust the digital balance.
8. Determine the area of cross-section of the tube. Suspend the empty glass tube as shown in Figure 2 and find its weight in zero magnetic field.
9. Using the DC power supply, vary the current from 0 to 3.5 A in steps of 0.2 A and in each case find the weight of the empty glass tube.

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10. Fill the tube with the given sample (say  $\text{FeCl}_2$ ) to about 3/4ths of the tube. Find the weight of the filled glass tube to an accuracy of 10 mg. in zero magnetic field.
11. As before, find the weight of the filled glass tube in different applied magnetic fields (both for the increasing and decreasing fields).
12. Repeat the experiment with one or two more substances.

**Calculation**

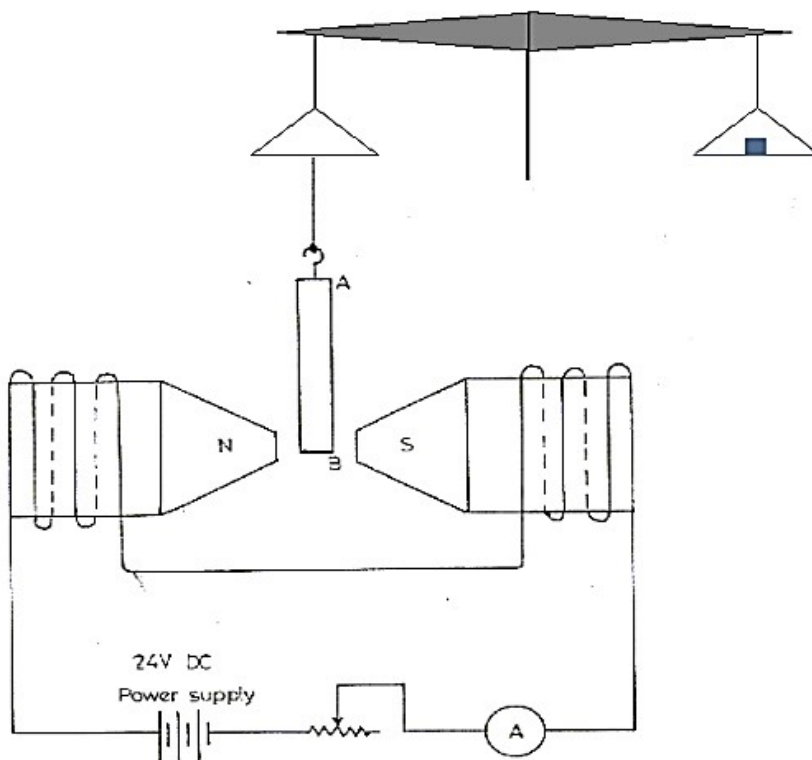
When the magnetic force is measured in terms of weight Equation (1) becomes,

$$mg = A \frac{\mu_0 \chi_m}{2} (H_1^2 - H_2^2) \approx A \frac{\mu_0 \chi_m}{2} H_1^2$$

Plot a graph between  $m$  and  $H^2$  to determine the susceptibility. This gives the susceptibility of a given volume. Compute the molar susceptibility of the sample and try to find the following:

- What is smallest susceptibility change that can be measured in the instrument?
- Is this sufficient to detect diamagnetism?
- Can you use this method for ferromagnets?
- Are there gradients in the other two perpendicular directions?
- When can we neglect their effect?

Figure 2 illustrates the conventional Gouy balance. NS is an electromagnet with power supply and AB is the experimental glass tube.



**Fig. 2** The Conventional Gouy Balance

### Important Instructions

1. Reduce the current through the coils to zero slowly and then switch off the power supply.
2. DO NOT change the distance between the pole-pieces.
3. Switch off the digital balance. The glass tube is taken out of the balance and kept on the table. The power supply to the electro magnet is also turned off.

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### Observation Tables

Record your observations in the following table and calculate the result using the given formula.

Table I

S.No.	Wt. of the empty glass tube (gm)	Current through the coils (A)	Magnetic field (Gauss)

Table II

S.No.	Wt. of the substance (gm)	Current through the coils (A)	Magnetic field (Gauss)

Below, is a table of some materials and their accepted magnetic susceptibilities and densities (SI units).

*Table 1 Magnetic Susceptibilities and Densities*

Material	Magnetic Susceptibility	Density ( $10^3 \text{ kg/m}^3$ )
Aluminum	$1.65 \times 10^{-5}$	2.70
Copper	$-5.46 \times 10^{-6}$	8.96
Lead	$-2.30 \times 10^{-5}$	11.36
Tin	$-3.74 \times 10^{-5}$	7.28
Titanium	$1.51 \times 10^{-4}$	4.50
Zinc	$-9.15 \times 10^{-6}$	7.12
Water	$-9.04 \times 10^{-5}$	1.00

## 16. SUSCEPTIBILITY BY QUINCKE'S METHOD

**Aim:** To determine the volume magnetic susceptibility of Manganese Sulphate ( $\text{MnSO}_4$ ) solution at different concentrations.

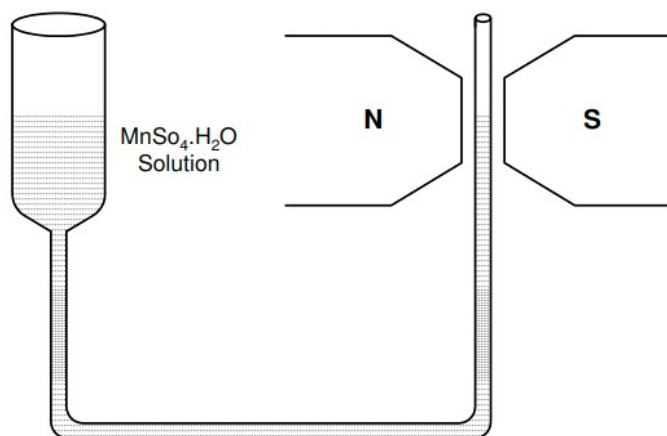
### Theory

The Quincke's method is used to determine magnetic susceptibility of a diamagnetic or paramagnetic substances in the form of a liquid or an aqueous solution. When an object is placed in a magnetic field, a magnetic moment is induced in it. Magnetic susceptibility  $\chi$  is the ratio of the Magnetization  $I$  (Magnetic Moment Per Unit Volume) to the applied Magnetizing Field Intensity  $H$ . The magnetic moment can

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be measured either by force methods, which involve the measurement of the force exerted on the sample by an inhomogeneous magnetic field or induction methods where the voltage induced in an electrical circuit is measured by varying magnetic moment. The Quincke's method like the Gouy's method belongs to the former class.

The Quincke's method is specifically used for the determination of magnetic susceptibilities of many liquids, aqueous solutions and liquefied gases. Here we are determining the susceptibility of  $\text{MnSO}_4$  solution (which is paramagnetic) at different concentrations. The schematic diagram of experimental set-up used for Quincke's method is shown below in Figure 1.



*Fig. 1 Schematic Diagram of Quinck's Setup*

### Materials Required

Quinck's tube with stand, Sample of  $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ , R.D. Bottle, Travelling Microscope, Electromagnet, Constant Current Power Supply, Digital Gauss Meter

### Procedure

1. Test and ensure that each unit (Electromagnet and Power Supply) is functioning properly.
1. The Manganese Sulphate ( $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ ) solution under investigation is placed in a vertical U-tube with one limb of wide bore and the other with narrow bore.
3. The narrow limb is placed in between the pole pieces of the electromagnet.
4. Remember that the surface of the liquid in the narrow limb must lie at the line of centres of the pole pieces when the field is off.
5. When the current is switched ON a strong field is appeared at upper surface of the narrow column while the lower portion will be in a state of comparatively weak field.
6. Hence a force will act upon the column and if the liquid is paramagnetic it will rise.

7. Measure the density ‘ $\rho$ ’ of the specimen (liquid or solution) by specific gravity bottle.
8. If the mass of empty bottle is  $w_1$ , filled with specimen  $w_2$  and filled with water  $w_3$ , then,

$$\rho = \rho_{water} \frac{w_2 - w_1}{w_3 - w_1}$$

9. Focus the microscope on the meniscus and take reading.
10. Apply the magnetic field  $H$  and note its value from the calibration. Check whether the meniscus rises up or descends down. It rises up for paramagnetic liquids and solutions while descends down for diamagnetics.
11. Readjust the microscope on the meniscus and take reading. The difference of these two readings gives  $h$  for the field  $H$ .
12. The magnetic field between the poles of the magnet does not drop to zero even when the current is switched OFF.
13. There is a residual magnetic field  $R$  which requires a correction.

### Determination of Density $\rho$

Measure the density ‘ $\rho$ ’ of the specimen (liquid or solution) by specific gravity bottle. If the mass of empty bottle is  $w_1$ , filled with specimen  $w_2$  and filled with water  $w_3$ , then calculate,

$$\rho = \rho_{water} \frac{w_2 - w_1}{w_3 - w_1}$$

Mass of specific gravity bottle ( $w_1$ ) = 19.698g

Mass of specific gravity bottle + water ( $w_3$ ) = 44.973g

Mass of specific gravity bottle + Solution ( $w_2$ ) = 56.173g

$$\rho = \frac{w_2 - w_1}{w_3 - w_1} = \frac{36.475}{25.275} = 1.443 \text{ g/cm}^3$$

### Calculation of Susceptibility

The Ambient Temperature will be 293 K. The mass susceptibility  $\chi'$  is given by  $\chi/\rho$  and the molar susceptibility  $\chi''$  by  $\chi'$  where  $\chi$  is the molecular weight of the specimen. In the case of solutions, correction must be made for the diamagnetic contribution of water. If the number of water molecules per unit volume is not very different in the solution from that in pure water,

In general if  $m_s$  is the mass of the salt dissolved in  $m_w$  of water, then,

Mass susceptibility of the salt, can be obtained from this relation.

**Result:** Record the observations and calculate the result.

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## 17. REFLECTION GRATING SPECTROMETER.

**Aim:** Determining the Wavelength of different colours in the spectrum using Reflection Grating.

### NOTES

#### Theory

Reflection Grating - A type of diffraction grating comprising grooves ruled into a surface that can be either plane or concave. In a Distributed Feedback Laser (DFB Laser), a diffraction grating with a concave surface serves to focus light without affecting the spectra.

In a transmission grating the diffracted light is passed through at an angle equal to the diffraction angle. For reflective gratings, the light is first diffracted by the grating and then reflected by the coating at an angle equal to the diffraction angle.

#### Components Required

Spectrometer, Grating and Mercury Vapour Lamp, Telescope, Vernier scale, Collimator

#### Procedure

1. The preliminary adjustments of the spectrometer are made.
2. The grating is set for normal incidence. The slit is illuminated by mercury vapour lamp.
3. The telescope is brought in a line with the collimator and the direct image of the slit is made to coincide with the vertical cross wire.
4. The readings of one Vernier are noted. The Vernier table is firmly clamped.
5. Now, the telescope is rotated exactly through  $90^\circ$  and is fixed in this position.
6. The grating is mounted vertically on the prism table with its ruled surface facing the collimator.
7. The Vernier table is released and is slowly rotated till the reflected image coincides with the vertical cross wire.
8. The leveling screws are adjusted so that the image is at the centre of the field of view of the telescope.
9. The prism table is fixed and after making fine adjustments with the tangential screw, the readings of the Vernier are noted.
10. Now, the angle of incidence is  $45^\circ$ . The Vernier table is then released and rotated exactly through  $45^\circ$  in the proper direction so that the surface of the grating becomes normal to the incident light.
11. The Vernier table is firmly clamped in this position.
12. The telescope is then released and is brought to observe the direct image. On the either side of the direct image, the diffraction spectra are seen.

13. The telescope is turned slowly towards the left so that the vertical cross wire coincides with the violet lines of the first order.
14. The readings of the Vernier are taken. The vertical cross wire is then made to coincide with the other lines on the left and the
15. Vernier readings are taken in each case. The telescope is then moved to the right and the reading of different lines is similarly taken.
16. The difference between the readings on the left and right on the same Vernier is determined for each line.
17. The mean value of this difference gives  $2\theta$ -twice the angle of diffraction. Thus the angle of diffraction  $\theta$  for each spectral line is determined.
18. The wavelength of the green line is  $546.1 \times 10^{-9}\text{m}$ . The number of lines per meter (N) of the grating is calculated.
19. Using this value of N, the wavelengths of the other prominent lines in this spectrum are calculated.

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### Procedure for Simulator

The simulation virtualizes the Mercury spectrum experiment. The user can use a Grating Spectrometer to measure the Wavelengths of Yellow, Green, Violet and Red lines in the Visible Spectrum of Mercury.

### Variable Region

1. **Telescope Calibrate Slider:** This slider helps the user to change the focus of telescope.
2. **Start Button:** Helps the user to start the experiment after setting the focus of telescope. The Start Button can be activated only if the focus of the telescope is proper.
3. **Light Toggle Button:** Helps the user to switch the lamp ON or OFF.
4. **Grating Toggle Button:** Helps the user to place or remove the grating.
5. **Telescope Angle Slider:** This slider helps the user to change the angle of telescope.
6. **Vernier Angle Slider:** This slider helps the user to change the angle of the Vernier.
7. **Telescope Angle Slider:** Helps make minute changes of the telescope angle.
8. **Calibrating Telescope Button:** Helps the user to calibrate the telescope after starting the experiment, if needed.

### Procedure for Simulation

#### To Standardize the Grating

- Turn the telescope to obtain the image of the slit.
- Turn the telescope to both sides to obtain green lines. Note the reading of both the Vernier's.

**NOTES**

- Calculate the difference in the reading to obtain the diffraction angle. Then from the equation, number of lines per unit length of the grating can be calculated.

**To Calculate the Wavelength of Different Lines**

- Obtain the direct image.
- Telescope is moved to make the cross-wire coincide with each line of the spectrum.
- Note the readings on the Vernier's and calculate the diffraction angle.
- Then calculate the wavelength of each colour.

**Observations and Calculations**

**Standardization of Equipment**

Green, $\lambda$ (nm)	Left		Right		Difference reading ( $2\theta$ )		Mean $\theta$	$N = \sin\theta/n\lambda$
	Ver I	Ver II	Ver I	Ver II	Ver I	Ver II		

For green light,  $\lambda = 546.1 \text{ nm}$

**Determination of Wavelength for Prominent Lines**

Color	Left		Right		Difference reading ( $2\theta$ )		Mean $\theta$	$\lambda = \sin\theta/nN$
	Ver I	Ver II	Ver I	Ver II	Ver I	Ver II		
Yellow I								
Yellow II								
Blue-Green								
Violet I								
Violet II								

**Results**

- The wavelength of Yellow I = .....nm  
 The wavelength of Yellow II = .....nm  
 The wavelength of Blue-Green = .....nm  
 The wavelength of Violet I = .....nm  
 The wavelength of Violet II = .....nm