

Lab Manual

M.Sc. Second Semester
(PHY555a)

General & Electronics Experiments

Central Department of Physics
Tribhuvan University, Kirtipur
Feb 2018

LIST OF GENERAL EXPERIMENTS

EXPERIMENT – 1

Study the absorption of β -particle by using (a) Aluminium and (b) Copper absorber and estimate the end-point energy of the given β -source.

EXPERIMENT 2

Study the absorption of α -particle in the air using (a) Am-241 and (b) Ra-226 source and end-window counter.

EXPERIMENT 3

Study the resistance versus Temperature curve of the given thermistor material. Also design and study its use as a sensor.

EXPERIMENT 4

Study the Hall coefficient of given n- & p-type materials and obtain the charge carrier density in each case and study the Hall mobility. (b) Also design and study use of n- & p- type materials to apply as fluxmeter probe.

EXPERIMENT 5

Study the magnetic susceptibility of given diamagnetic and paramagnetic substances

EXPERIMENT 6

Lattice Dynamics: (a) Study the monoatomic lattice vibration. Hence obtain the cut-off frequency of the given materials. (b) Study the diatomic lattice vibrations and determine the optical band gap

EXPERIMENT 7

Study the heat capacity of given materials (use 0.1° C sensitivity)

EXPERIMENT 8

Study the hysteresis loss of the given materials and compare them.

EXPERIMENT 9

Study the photocell and verify inverse square law. Hence determine Planck's constant and use it as a detector.

LIST OF ELECTRONICS EXPERIMENTS

EXPERIMENT: 1

STUDY THE TRI-STATE LOGIC (TSL) CIRCUIT AND HENCE VERIFY ITS TRUTH TABLE

EXPERIMENT: 2

TO STUDY THE MULTIPLEXER AND VERIFY ITS TRUTH TABLE

EXPERIMENT: 3

DESIGN AND STUDY THE 1-BIT DIGITAL COMPARATOR CIRCUIT

EXPERIMENT: 4

TO STUDY THE DEMULTIPLEXER AND VERIFY ITS TRUTH TABLE

EXPERIMENT: 5

DESIGN AND STUDY THE 1- BIT MEMORY CIRCUIT

EXPERIMENT: 6

TO DESIGN THE DECIMAL-TO-BINARY CODED DECIMAL (BCD) ENCODER AND VERIFY THE CONVERSION

Central Department of Physics
General Experiment Working Cycle
M.Sc. Second Semester

SN	Name of the Experiment	GROUP A		GROUP B	
		R.N.	R.N.	R.N.	R.N.
1	Study the absorption of β -particle by using (a) Aluminium and (b) Copper absorber and estimate the end-point energy of the given β -source.	1-3	31-33	61-63	91-93
2	Study the absorption of α -particle in the air using (a) Am-241 source and end-window counter.	4-6	34-36	64-66	94-96
3	Study the absorption of α -particle in the air using (a) (b) Ra-226 source and end-window counter.	7-9	37-39	67-69	97-99
4	Study the resistance versus Temperature curve of the given thermistor material. Also design and study its use as a sensor.	10-12	40-42	70-72	100-102
5	Study the Hall coefficient of given n- & p-type materials and obtain the charge carrier density in each case and study the Hall mobility. (b) Also design and study use of n- & p- type materials to apply as fluxmeter probe.	13-15	43-45	73-75	103-105
6	Study the magnetic susceptibility of given diamagnetic and paramagnetic substances	16-18	46-48	76-78	106-108
7	Lattice Dynamics: (a) Study the monoatomic lattice vibration. Hence obtain the cut-off frequency of the given materials. (b) Study the diatomic lattice vibrations and determine the optical band gap	19-21	49-51	79-81	109-111
8	Study the heat capacity of given materials (use 0.1° C sensitivity)	22-24	52-54	82-84	112-114
9	Study the hysteresis loss of the given materials and compare them.	25-27	55-57	85-87	115-117
10	Study the resistance versus Temperature curve of the given thermistor material. Also design and study its use as a sensor.	28-30	58-60	88-90	118-120

EXPERIMENT – 1

Study the absorption of β -particle by using (a) Aluminium and (b) Copper absorber and estimate the end-point energy of the given β -source.

DESCRIPTION

Strontium-90 is a commonly used beta emitter used in industrial sources. It is also used as a thermal power source in radioisotope thermoelectric generator power packs. These use heat produced by radioactive decay of strontium-90 to generate heat, which can be converted to electricity using a thermocouple. Strontium-90 has a shorter half-life, produces less power, and requires more shielding than Plutonium-238, but is cheaper as it is a fission product and is present in a high concentration in nuclear waste and can be relatively easily chemically extracted. Strontium-90 based RTGs have been used to power remote lighthouses.

Strontium-89 is a short lived beta emitter which has been used as a treatment for bone tumors, this is used in palliative care in terminal cancer cases. Both strontium-89 and strontium-90 are fission products.

In the radioactive decay of nuclides emitting beta particles, all beta particle energies are possible from zero to a maximum called the endpoint energy. The endpoint energy in beta decay corresponds to the mass difference between the parent and daughter nuclides. The average energy of the beta particles is less than one half of the endpoint energy. The remaining energy is carried away by the anti-neutrino (in the case of beta- decay) or the neutrino (in the case of beta+ decay).

WORKING FORMULA

The β -decay is a random process. Though it can be studied using laws of radioactivity, which is based on the laws of probability. The intensity of β -particle after passing the thickness 'x' of any absorber material having β -absorption coefficient is given by,

$$I = I_0 e^{-\mu x} \quad (1)$$

Here I_0 is the intensity of β -particle at $x = 0$. The value of I is proportional to the number of β -particles in the beam which in turn proportional to the number of counts of β -particle per second given by GM counter. If N_0 and N are the number of counts corresponding to I_0 and I , then

$$N = N_0 e^{-\mu x}$$

Taking log, we get

$$\ln N = \ln N_0 - \mu x \quad (2)$$

If we make a plot between $\ln N$ versus distance, the negative slope of the line gives the absorption coefficient. The maximum range R of the β -particle is determined by extrapolation of absorption curve for zero counting (or up to the level of background). The maximum range is related to the maximum particle energy E by this empirical formula,

$$E = \frac{R + 0.133}{0.542} \quad (3)$$

Where R is measured in gm/cm^2 (thickness \times density) and E is in MeV.

EXPERIMENTAL SET-UP

Go to C. L. Arora or any other B.Sc. Laboratory work book for the detail procedure. Your teacher will describe the method. [Note: The distance between source and the absorber material should be less than that of the distance between GM tube and the absorber material]

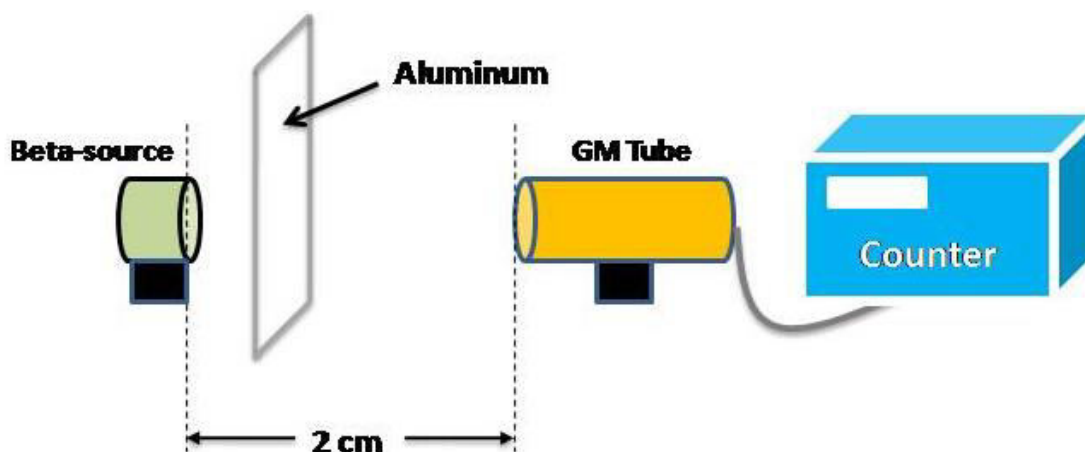


Figure 1: Experimental Set up

OBSERVATION

(a) For operating voltage of GM Tube (do NOT put any source for calibrating GM tube)

S.N.	Voltage (Volts)	Count rate per 30 seconds (at least 10 readings)	Average count/30 sec
1	300		
2	325		
3	350		
4	375		
5	400		
6	425		
7	450		
8	475		

The plateau curve of GM tube describe its response towards the decays, shown below:

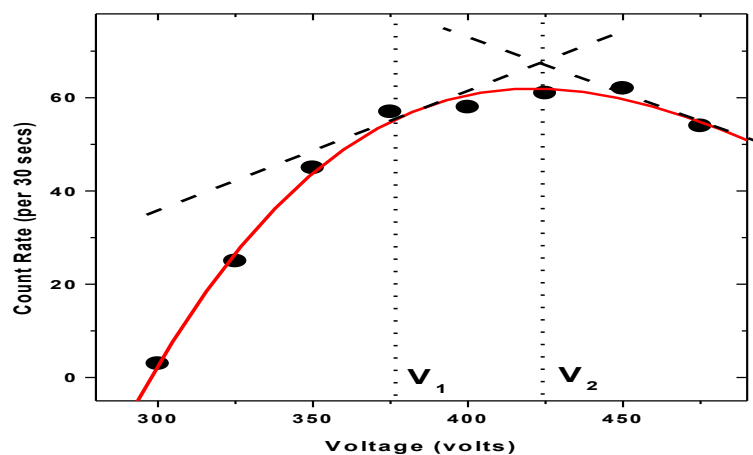


Figure 3: Plateau Curve to calculate operating voltage of GM counter (do NOT use any radioactive source!)

From the graph, $V_1 = \dots\dots\dots$ volt

$V_2 = \dots\dots\dots$ volt

Operating voltage is,

$$V = V_1 + (V_2 - V_1)/3 = \dots\dots\dots \text{ volt}$$

The background count at the operating voltage (= $\dots\dots\dots$ volt):

--	--	--	--	--	--	--	--	--	--

The average background count per 30 sec is $\dots\dots\dots$

The background count (**B**) per second is $\dots\dots\dots$

(b) Absorption by the Al absorber

Beta Source: $\dots\dots\dots$

Distance between b-source and the window of GM tube = $\dots\dots\dots$

(this distance should be less than 2 cm)

S.N.	Thickness of Al absorber (mm)	Count Rate / 30Seconds (N)					Average (N)	Background Subtracted (N-B)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

BEST FIT CALCULATION

Let $y = \ln(C)$ and x is the thickness of the Aluminium absorber, then

$$y = mx + c \quad (4)$$

represents the best fitted line (shown in Figure 5), where m is the slope and c the intercept.

Taking sum, equation (4) takes this form:

$$\Sigma y = m \Sigma x + nc \quad (5)$$

Multiplying (4) by Σx ,

$$\Sigma yx = m \Sigma x^2 + c \Sigma x \quad (6)$$

Multiplying (5) by Σx and (6) by n and solving these expression for the slope (m), we get,

$$m = \frac{n \Sigma yx - \Sigma y \Sigma x}{n \Sigma x^2 - (\Sigma x)^2} \quad (7)$$

and intercept is given by,

$$c = \frac{\Sigma y - m \Sigma x}{n} \quad (8)$$

In order to best fit, you need to calculate following variables in this tabular form:

SN	Count / 30 sec(O)	Count / sec (N)	Corrected Count (N-B)	$y_i = \ln N$	x_i (mm)	x_i^2	$x_i y_i$
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
Sum (Σ) =							

PLOTTING

Figure 4 shows the expected plottings (students need to use graph papers with pencil) between calculated the refractive index with suger concentration.

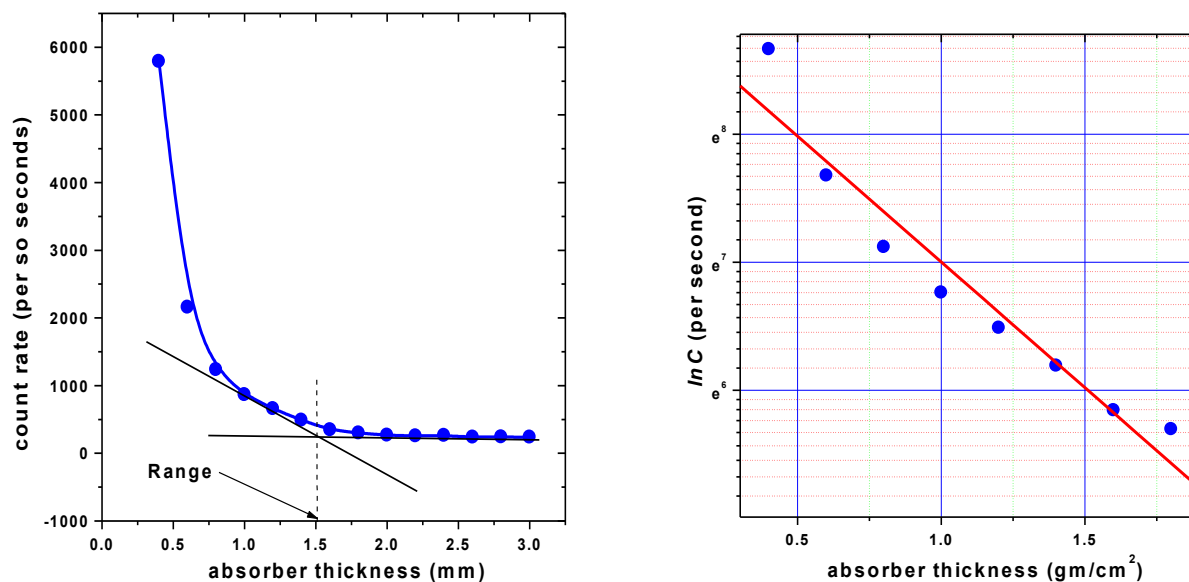


Figure 3: Count rate (in *linear* scale: left & in *logarithmic* scale: right) versus time [based on observed data at CDP]. The nature of the distribution seems like exponential decay (left). The nature of the distribution fits the laws of radioactivity, $\ln C$ is proportional to absorber thickness (b). You need to fit your observed data using (7) and (8).

We get

$$m = \frac{\Delta y}{\Delta x} =$$

and intercept

$$c = \frac{y - mx}{1} =$$

We use the value of slope to find the value of half life of the prepared liquid source.

$$\text{absorption coefficient}(\mu) = -m = \dots\dots\dots \text{cm}^2/\text{gm}$$

To find the end point energy of given beam of b-particles, the range R (Figure 3) can be used.

$$E = \frac{R + 0.133}{0.542} = \dots\dots\dots \text{MeV}$$

ERROR ANALYSIS

SN	$y_i = \ln N$	x_i (mm)	$x_i - \bar{x}$
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
			$D =$

The error in the slope is

$$\Delta m = \left[\left(\frac{\sum d_i^2}{n-2} \right) \frac{1}{D} \right]^{1/2} = \dots\dots\dots$$

Here

$$D = \sum (x_i - \bar{x})^2 \text{ and } d = \sum y_i - m \sum x_i - c$$

Note: Repeat the whole process for Copper absorber.

RESULT

- (1) It is found that the absorption coefficient β -particles emitted from the given source in the **aluminium** absorber of is \pm The end point energy of β -particle is found to be MeV.
- (2) It is found that the absorption coefficient β -particles emitted from the given source in the **Copper** absorber of is \pm The end point energy of β -particle is found to be MeV.

INTERPRETATION OF YOUR RESULT

You need to interpret your result yourself.

PRECAUTION

Write down precaution that you faced or experienced during the experiment.

EXPERIMENT 2

Study the absorption of α -particle in the air using (a) Am-241 and (b) Ra-226 source and end-window counter.

Objectives of the Experiment

- (a) Study the radioactivity of given α -emitters.
- (b) Study the α -absorption in the air using end-window counter. Find its absorption coefficient.
- (c) Find the number of α -nuclei present in your source using given activity. What will be the number after 1 year, 10 years?
- (d) Study the wave properties of α -particles by verifying inverse square law.
- (e) Study the ionization energy of α -particles.

Absorption of α -particles in the gases

Interaction of heavy charged particles with matter In nuclear physics, the term “heavy particles” is applied to particles with mass that is much larger than electron mass. Examples of heavy particles are the proton (e.g., He nucleus, which is composed of two protons and two neutrons). When radiation is composed of charged particles, the main quantity characterizing interaction of radiation with matter is the average decrease of particle kinetic energy per unit path length. This quantity is called the stopping power of the medium and is denoted S . The main mechanism of the energy loss of heavy charged particles (and electrons with energies of the order of a few MeV or less) is ionization or excitation of the atoms of matter (excitation is the process when internal energy of the atom increases, but it does not lose any electrons). All such energy losses are collectively called ionization energy losses (this term is applied to energy losses due to excitation, too). Atoms that are excited or ionized due to interaction with a fast charged particle lie close to the trajectory of the incident particle (at a distance of a few nanometers from it). The nature of the interaction that causes ionization or excitation of atoms is the so-called Coulomb force which acts between the incident particles and electrons of the matter.

Americium-241

Americium-241 is made in nuclear reactors, and is a decay product of plutonium-241. The element americium (atomic number 95) was discovered in 1945 during the Manhattan Project in USA.

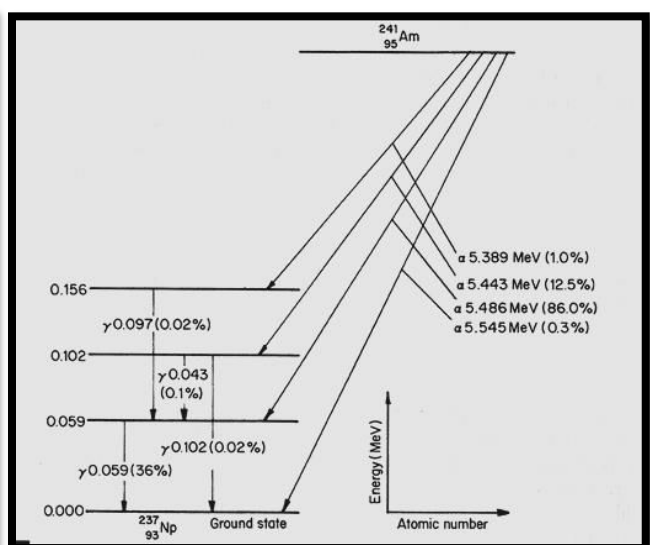
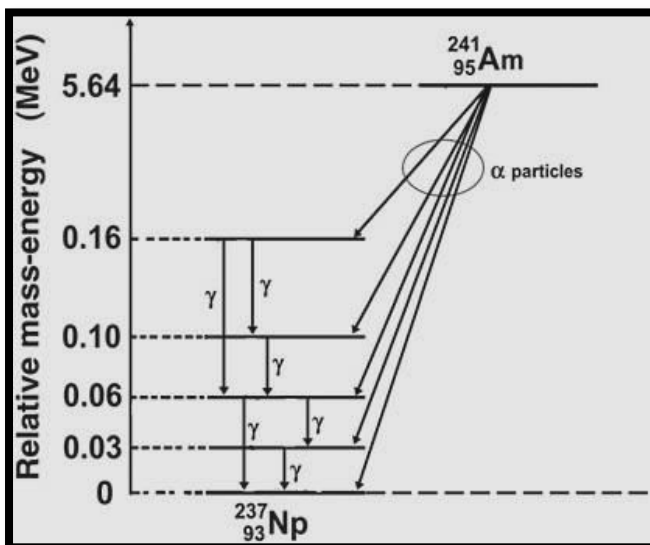


Figure 1: Decay Scheme of Am-241

The first sample of americium was produced by bombarding plutonium with neutrons in a nuclear reactor at the University of Chicago. Americium-241, with a half-life of 432 years, was the first americium isotope to be isolated, and is the one used today in most domestic smoke detectors. Am-241 decays by emitting alpha particles and gamma radiation to become neptunium-237. The most common application of americium is of the Am-241 isotope as an ionization source in smoke detectors, and most of the several kilograms of americium recovered each year is used in this way at present.

Ra-226

The nuclide Ra 226 is an isotope of the element radium (atomic number 88, chemical symbol Ra). There are 226 nucleons in the nucleus consisting of 88 protons and 138 neutrons. Ra 226 is radioactive with a half-life of 1600 years. It decays through alpha emission. The alpha particle energy with the highest emission probability is at 4.7843 MeV followed by 4.601 MeV. Additional alpha particles are also observed – indicated by the dots. In contrast to beta emission (where only two beta energies are given – the most probable and the highest energy respectively), the alpha particle energies are listed according to decreasing emission probability.

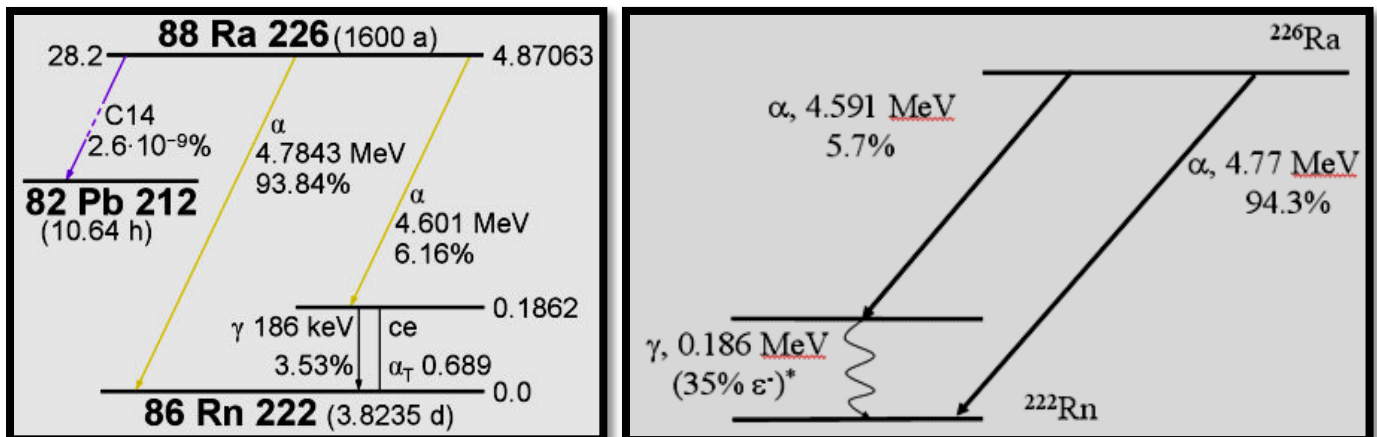


Figure 2: Decay Scheme of Ra-226

Laws of Radioactivity

Activity of radioactive substance $A(t)$ is at any time t proportional to number of radioactive particles $N(t)$,

$$A(t) = \lambda \cdot N(t) \quad (1)$$

The number of radioisotope present at time t , decays exponentially with time, i.e.,

$$N(t) = N_0 \cdot e^{-\lambda \cdot t} \quad (2)$$

In terms of mass absorption coefficient, we express $\lambda t = \mu_m x$. One can calculate mass absorption coefficient using above expression. These ionizing radiation shows wave properties and hence satisfies inverse square law, i.e., $N(t)$ is inversely proportional to the square of the distance between the GM tube and the source.

Ionization Energy of a-particles

The quantum mechanical calculation of the stopping power due to ionization energy losses is given by

$$S = \frac{1}{4\pi\epsilon_0^2} \frac{z^2 e^4 n}{m_e v^2} \left\{ \ln \frac{2m_e v^2}{I(1-\beta^2)} - \beta^2 \right\} \quad (3)$$

where v is the particle velocity, z is its charge in terms of elementary charge e ("elementary charge" e is the absolute value of electron charge), n is the electron concentration in the material, m_e is electron mass, ϵ_0 is the electric constant ($\epsilon_0 = 8.854 \times 10^{-12}$ F/m), β is the ratio of particle velocity and velocity of light c (i. e. $\beta \equiv v/c$), and the parameter I is the mean excitation energy of the atomic electrons (i. e., the mean value of energies needed to cause all possible types of excitation and ionization of the atom). This formula is applicable when v exceeds 10^7 m/s (this corresponds to alpha particle energy of 2 MeV).

Smoke Detectors

Americium-241 emits alpha particles and low energy gamma rays. The alpha particles emitted by the Am-241 collide with the oxygen and nitrogen in air in the detector's ionisation chamber to produce charged particles (ions). A low-level electric voltage applied across the chamber is used to collect these ions, causing a steady small electric current to flow between two electrodes. When smoke enters the space between the electrodes, the smoke particles attach to the charged ions, neutralizing them. This causes the number of ions present – and therefore the electric current – to fall, which sets off an alarm. The radiation dose to the occupants of a house from a domestic smoke detector is essentially zero, and in any case very much less than that from natural background radiation. The alpha particles are absorbed within the detector, while most of the gamma rays escape harmlessly. The small amount of radioactive material that is used in these detectors is not a health hazard and individual units can be disposed of in normal household waste. Even swallowing the radioactive material from a smoke detector would not lead to significant internal absorption of Am-241. Americium dioxide is insoluble, so will pass through the digestive tract without delivering a significant radiation dose. (Americium-241 is however a potentially dangerous isotope if it is taken into the body in soluble form. It decays by both alpha activity and gamma emissions and it would concentrate in the skeleton).

Instrumentation

(a) End-window counter with cable for α , β , γ and X-rays



Figure 3: End-window tube and counter

Self-quenching Geiger-Müller counter tube, in a plastic housing, with a very thin mica end-window which also allows the registration of soft β radiation. With a permanently attached cable. Complete with a protective cap for the mica window.

Technical Data

• Gas filling: neon, argon, halogen	• Dead time: approx. 100 μ s
• Mean operating voltage: 450 V	• Service life: $> 10^{10}$ pulses
• Connection: screened cable, 55 cm long, with coaxial plug	• Background in plateau: approx. 0.2 pulses/s
• Plateau length: 200 V	• Responsivity to γ radiation: approx. 1%
• Relative plateau slope: $< 0.05\%/V$	• End-window: 9 mm diam.

(b) Counter S

For counting of counter tube pulses, pulse rates or other electrical pulses as well as for frequency and time measurement. Especially suitable for student work. With 5-digit LED display, internal loudspeaker and special counter tube input with internal high-voltage supply, 2 photoelectric barrier inputs, operation via built-in keys. Plug-in power supply unit included.

Technical Data

• Measuring ranges: Frequency: 0 ... 99999 Hz Time: 0 ... 99999 s, 0 ... 99.999 ms	• Pulse input and output: 4 mm safety sockets
• Gate times for counter tube: fixed 10s, 60s, 100s,	• Sensitivity: TTL-compatible
• manual up to 9999 s • Display: 5-digit LED display	• Photoelectric barrier inputs: 6-pole DIN-sockets
• Integrated counter tube voltage : 500 V Inputs and outputs	• Power supply: 12 V AC/DC via plug-in power supply(included)
• Counter tube input: coaxial socket	• Dimensions: 20.7 cm x 13 cm x 4.5 cm

Procedure

- (1) You do not need to find out operating voltage of the GM tube. It is a very special GM tube names as '*end window counter*' with halogen gases capable of detecting not only β and γ , but also α (strong ionizing power) and X-rays (strong penetrating power). The operating voltage of this tube is 450 V and it is supplied through 12 V AC/DC via plug-in power supply.
- (2) You need to connect the cable of end window counter and the GM Counter S in a gentle way. Adjust knobs to GM manual at first. Do not place the radioactive sources nearby the set-up. Take readings for about 5 minutes. This will discharge the effect of previous measurements.
- (3) Now observe background counts by adjusting knob at 60 seconds. Take at least 20 observations for the background. Find the mean, standard deviation and standard error of background counts.
- (4) Now place Am-241 at 5 cm far from the window of end-window counter. Take at least 20 readings for the interval of 60 seconds.

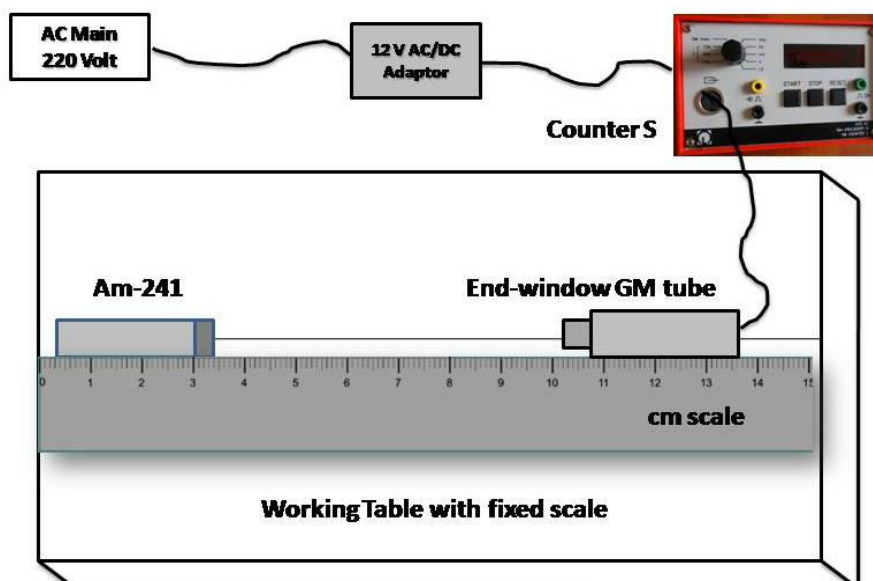


Figure 4: Experimental set-up for the measurement of α -absorption in the air. A fixed scale with a hard board and fixed end-window tube and fixed source in a wooden box is preferred.

- (5) Now decrease the distance by 0.50 cm carefully (if needed set the distance yourself) and observe the reading (see Figure 3). For each position, take at least 20 observations.
- (6) Using the standard value of half life of Am-226 and the given value of the activity, you can calculate disintegration constant and hence the mass absorption coefficient.
- (7) Since you have the accurate values of distances between the source and the detector, you can verify inverse square law.
- (8) Try to calculate the number of radioactive atom present in your source. Similarly velocity of emitted α -particles can be calculated by using its energy. Using these values one can calculate stopping power.
- (9) You need to show best fitted graphs for the calculation of mass absorption coefficient and the inverse square law (Figure 4).

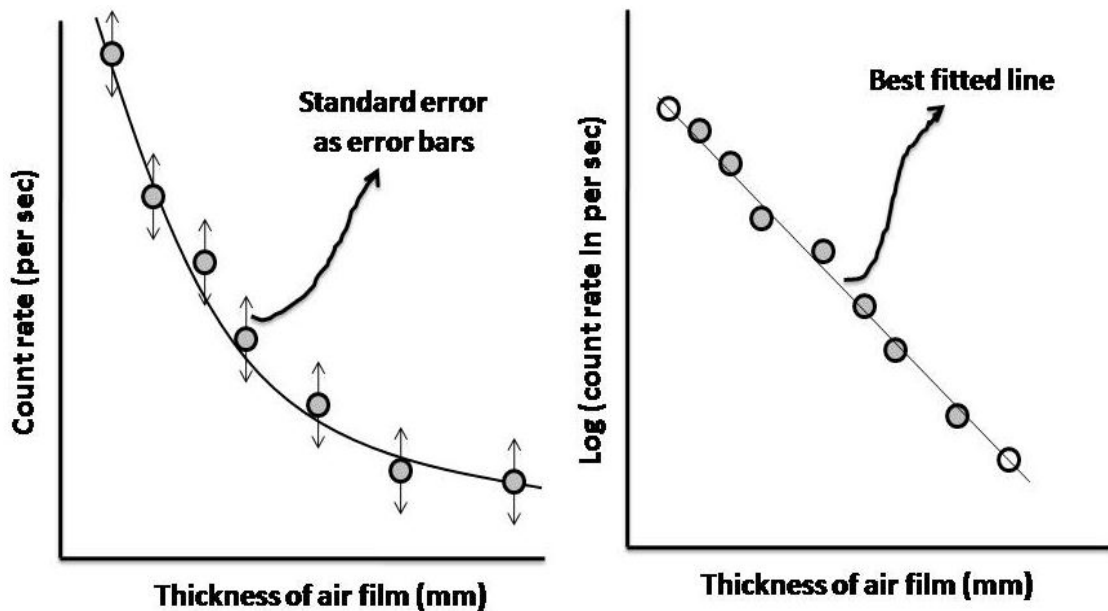


Figure 5: Count rate versus absorption of alpha particles by air.

- (10) Since you know the standard error of your all sets of data, you will be able to put error bars in your plot.
- (11) Repeat the whole process for Ra-226 and compare their results.

RESULT

Summarize your result here.

ERROR ANALYSIS

Use suitable method for error analysis (perform best fit and find standard error of your observation)

DISCUSSION

Interpret your plots and calculated values in the context of alpha interaction with the air in the laboratory.

EXPERIMENT 3

Study the resistance versus Temperature curve of the given thermistor material. Also design and study its use as a sensor.

DESCRIPTION

The thermistor is a semiconductor device which consists of a bead or disc of various oxides manganese, Nickel, cobalt, iron or other metals. A word thermistor is derived from thermal resistor. A thermistor is a device whose resistance varies quite markedly with temperature depending upon their composition. The thermistor can have either positive temperature coefficient or a negative temperature coefficient. The negative temperature coefficient type consists of a mixture of oxides of iron, nickel and cobalt. The positive temperature coefficient type is based on Barium titanate and shows a temperature increase of 50 to 200 times for a temperature rise of few degrees. These are used in temperature controlled switch.

WORKING FORMULA

A semiconductor material is characterized by the property that its conductivity increases sharply with rise in temperature. This is because the number of charge carrier is increased in an exponential manner as characterized by the factor $\exp\{-E_g/KT\}$. The resistance (R) of semiconductor material is given by

$$\left(\frac{1}{R}\right) = \left(\frac{1}{R_0}\right) e^{-\left(\frac{E_g}{KT}\right)} \quad (1)$$

Here R_0 is the resistance at highest temperature. Taking log both sides we get,

$$\log\left(\frac{1}{R}\right) = \log\left(\frac{1}{R_0}\right) - \frac{E_g}{KT} \quad (2)$$

The slope of the plot between $\log(1/R)$ and $(1/T)$ is $-(E_g/K)$. Thus, band gap of the given semiconductor material can be calculated if we linearly fit our observations, according to equation (2). The value of resistance can be measured with the balanced condition of Wheatstone Bridge, i.e., null deflection in the Galvanometer. Under Balancing condition:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad (3)$$

Since $R_3 = R_4$, thus $R_1 = R_2$. Here R_1 is the resistance of thermistor and R_2 is the resistance of bridge. The temperature is measured with the help of thermometer. The slope of straight line gives the band gap E_g of given semiconductor material.

EXPERIMENTAL SET-UP

Go to C. L. Arora or any other B.Sc. Laboratory work book for the detail procedure.

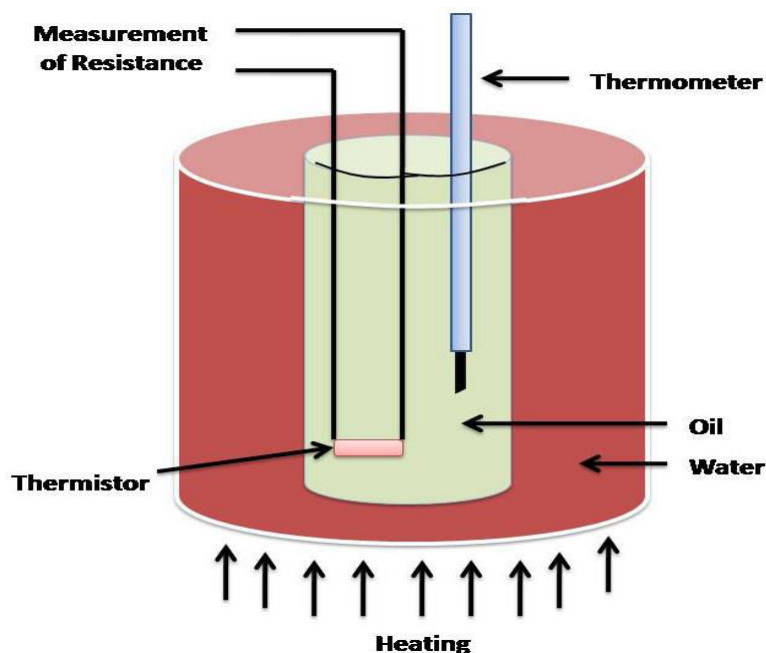


Figure 1: Experimental Set up

OBSERVATION

(a) For variation of resistance (*Note: Students need to keep 2 degree centigrade difference while taking observation. In addition, observation should be taken by increasing and decreasing temperature*)

S.N.	Temperature ($^{\circ}\text{C}$)		Resistance (Ω)	
	Increasing (I)	Decreasing (d)	Value (for I)	Value (for d)
1	30	92		
2	32	90		
3	34	88		
4	36	86		
5	38	84		
6	40	82		
7	42	80		
8	44	78		
9	46	76		
10	48	74		
11	50	72		
12	52	70		
13	54	68		
14	56	66		
15	58	64		
16	60	62		
17	62	60		
18	64	58		
19	66	56		
20	68	54		
21	70	52		
22	72	50		

23	74	48		
24	76	46		
25	78	44		
25	80	42		
27	82	40		
28	84	38		
29	86	36		
30	88	34		
31	90	32		
32	92	30		

The variation of resistance with temperature is shown in Figure 2 (below).

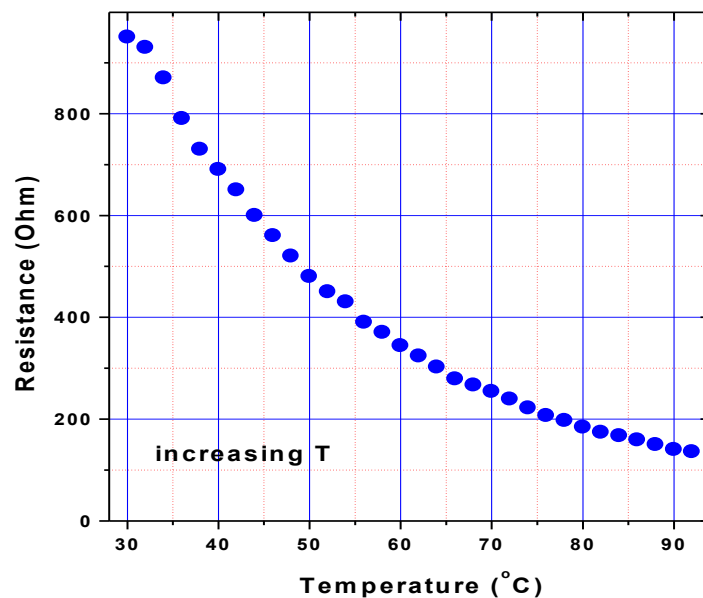


Figure 2: Variation of resistance with increasing temperature [students need to perform similar workout (observation, plotting and calculation) with decreasing temperature]

BEST FIT CALCULATION

Let $y = \log(1/R)$ and $x = 1/T$, then the working formula can be written in this form

$$y = mx + c \quad (4)$$

which represents the best fitted line (shown in Figure), where m is the slope and c the intercept.

Taking sum, equation (4) takes this form:

$$\Sigma y = m \Sigma x + nc \quad (5)$$

Multiplying (4) by Σx ,

$$\Sigma yx = m \Sigma x^2 + c \Sigma x \quad (6)$$

Multiplying (5) by Σx and (6) by n and solving these expression for the slope (m), we get,

$$m = \frac{n\sum yx - \sum y \sum x}{n\sum x^2 - (\sum x)^2} \quad (7)$$

and intercept is given by,

$$c = \frac{\sum y - m\sum x}{n} \quad (8)$$

In order to best fit, we need to calculate following variables in this tabular form:

SN	Temperature (in Kelvin)	Resistance (in Ohm)	$x = (1/T)$ $\times 10^{-3}$	$y = \ln(1/R)$	x^2	xy
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
Sum (Σ) =						

Note: Students need to perform second sets of calculation and best fit for the dataset taken by decreasing the temperature.

PLOTTING

Figure 4 shows the expected plottings (students need to use graph papers with pencil).

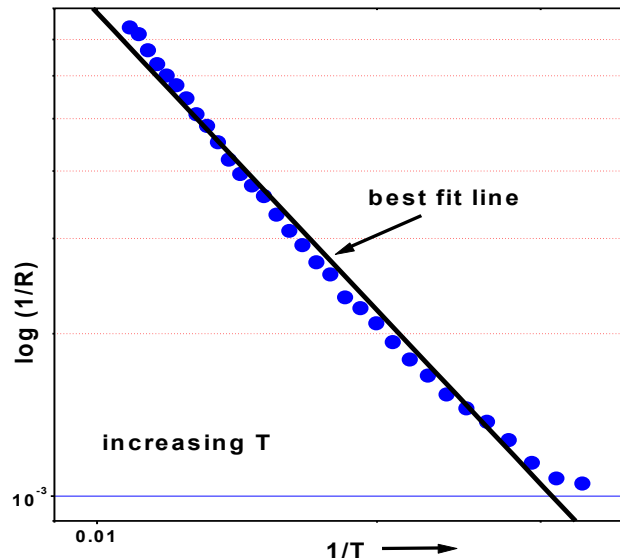


Figure 3: Inverse of resistance versus inverse of temperature plot with best fit line [based on observed data at CDP]. The slope of best fit line gives band gap of the given semiconductor.

We get

$$m = \dots =$$

and intercept

$$c = \dots =$$

We use the value of slope to find the value band gap in the given semiconductor.

$$\text{slope}(m) = \dots = \frac{E_g}{K}$$

Thus,

$$\text{Band Gap } (E_g) = K \times m = \dots \text{ J} = \dots \text{ eV}$$

Note: You will get two band gaps after taking first and second set of observations. These values can be average out.

Different Uses for Thermistors

A thermistor is a specific type of resistor that uses sensors to help regulate cold and heat. They can do more than simply regulate temperature. They are also used for voltage regulation, volume control, time delays, and circuit protection. These products are made up of ceramic and metal oxides, but it also contains circuits and wires. These resistors have many practical applications both in terms of manufacturing and personal products. Below, we will be going over some of the different uses and applications for thermistors throughout multiple industries.

Microwave

For those who have used a microwave, you have used a thermistor. They are used in these machines to determine and maintain internal temperature. Without the resistor in the microwave, there is a possibility of overheating in the unit. This could lead to potential fires.

Circuit Protector

If you have a power supply or surge protector in your home or office then you are also using a thermistor. Without a thermistor in this product, surges of energy would be uncontrolled. This could lead to overheating or too much electricity being pushed to whatever is plugged in. This could lead to some of your electronics shorting out.

Automotive

Cars, trucks, and buses all use thermistors. They are used to determine the temperature of oil and coolants. This is how you are able to know if your car is overheating or not. The thermistors are connected to indicators on the dashboard of the vehicle. Thermistors in cars do not prevent or regulate. Instead, they are used to gather information. This allows a driver to fix their car or truck before something serious happens.

Digital Thermometers

Have you ever wondered how digital thermometers are able to accurately gauge someone's temperature? This is possible because of thermistors. Just like with cars, these devices used to gather information rather than helping to maintain temperature.

Rechargeable Batteries

The ability to recharge a battery is only possible because of the help it gets. When you start charging batteries, there is a tendency for things to get hot. The low resistance of the thermistor allows it to stop the charging if things are getting too hot.

Thermistors are used in everyday life, and they are used in so many different ways.

PLAN A WORK USING THERMISTORS

You need to make a sketch regarding the use of the thermistor that you have in your laboratory. Plan it as a sensor in your design. Discuss with your colleague.

RESULT

It is found that the resistance of given thermistor increases with the decrease in the temperature. In addition, we found that the band gap in the given semiconductor iseV.

INTERPRETATION OF YOUR RESULT

You need to interpret your result yourself.

PRECAUTION

Write down precaution that you faced or experienced during the experiment.

EXPERIMENT 4

**Study the Hall coefficient of given n- & p-type materials and obtain the charge carrier density in each case and study the Hall mobility.
(b) Also design and study use of n- & p- type materials to apply as fluxmeter probe.**

AIM OF THE EXPERIMENT

After conducting this experiment students will understand

1. measurement the Hall voltage developed across the sample material.
2. measurement the Hall coefficient and the carrier concentration of the sample material

APPARATUS REQUIRED:

1. Electromagnets
2. Power Supply Unit for Electromagnets
3. Gauss Meter for Measuring Magnetic field
4. Power Supply Unit for Crystal
5. p or n semiconductor slice

THEORY:

When a magnetic field is applied perpendicular to current carrying conductors a voltage is developed across it in the direction perpendicular to both current and magnetic field. This phenomenon is called Hall Effect and voltage itself is known as Hall voltage.

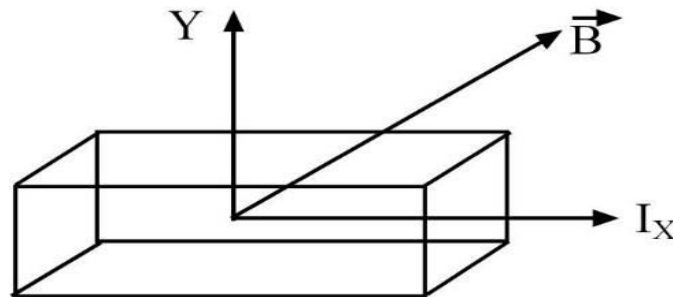


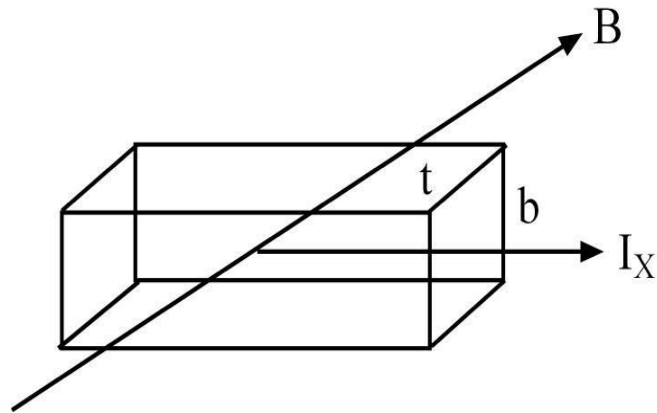
Fig. 1: Schematic representation of Hall Effect

If the current I_x passes in X-direction in the conductor a magnetic field B_z is applied in Z-direction, then Hall Voltage is developed in Y-direction. The sign of Hall Voltage depends on the nature of charge carriers. Experimentally it has found that Hall voltage

$$V_H \propto B, \quad V_H \propto j_x \& V_H \propto b$$

Where j_x current density and b is width of the specimen across which Hall Voltage is developed

So $V_H \propto B j_x b \Rightarrow V_H = R_H B j_x b$, R_H is constant for the given conductor and is known as Hall Coefficient



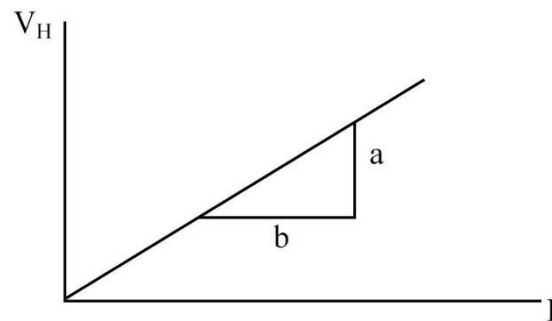
$$j_x = \frac{I}{b \times t}$$

$$V_H = R_H B \frac{I}{b \times t} \times b$$

$$R_H = \frac{V_H t}{BI}$$

It can be shown that

$$R_H = \frac{V_H t}{BI}$$



$$\text{Slope} = \frac{a}{b} = \frac{R_H B}{t}$$

Thus from the graph

$$R_H = \text{Slope} \times \frac{t}{B}$$

EXPLANATION:

Consider a semiconductor in which holes are assumed to move in the X-direction representing a current density

$$j_x = \frac{I_x}{b \times t}$$

When magnetic field $\vec{B}(0, 0, B)$ is applied. The holes experience magnetic force $\vec{F} = (\vec{v} \times \vec{B})q$ directed towards the upper force and creation these a surface of possible charges negative charges at the lower surface. Thus electric field directed in (-y) direction is developed inside the conductor and equilibrium is reached when the electric field force on the charges balances the magnetic force.

Thus at equilibrium $qE = qvB$

$$E = \frac{V_H}{b} \Rightarrow I_x = nevA = nev b \times t$$

$$\frac{V_H}{b} = vB, \Rightarrow \frac{V_H}{b} = \frac{I_x}{ne} \times \frac{B}{b \times t}$$

$$V_H = \frac{1}{ne} I_x \frac{B}{t} \quad \& \quad R_H = \frac{1}{ne}$$

HALL MOBILITY:

The gain in velocity per unit electric field is known as mobility (μ)

We have, $j = \sigma E$

$$\therefore nev = \sigma E$$

$$\Rightarrow \mu = \frac{v}{E} = \sigma \frac{1}{ne}$$

$= \sigma R_H$, where σ is conductivity of a material

PROCEDURE

1. Calibrated the magnetic field against magnetizing current by using a Hall probe and digital Gauss meter.
2. Measure the magnetic field, B with a gauss meter.
3. Connect the p or n semiconductor slice to constant power supply unit for crystal in their respective Sockets.
4. Measure Hall Voltage for both the directions of current and magnetic field(i.e. four observations for a particular value of current and magnetic field).
5. Change the value of I_x in steps and note corresponding value of I_x and V_H , Then plot a graph between V_H and I_x . It will be straight line whose slope will be given by $\frac{V_H}{I_x}$.

OBSERVATION

Table 1: Observation of Magnetic Field

No. of obs.	Current	Magnetic Field	
		In Gauss	In Tesla

Table 2: Different applied magnetic field (*We get different set of current and Hall voltage*)

No. of obs.	I_x (mA)	$B_z = \dots\dots$ (0V)	$B_z = \dots\dots$ (30V)	$B_z = \dots\dots$ (60V)	$B_z = \dots\dots$ (90V)	$B_z = \dots\dots$ (120V)
		V_H (mV)	V_H (mV)	V_H (mV)	V_H (mV)	V_H (mV)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

PLOTS:

(*you need to make plots for all voltajes (0V, 30V, 60V, 90V and 120 V) and fild slopes (m) from their best fits*)

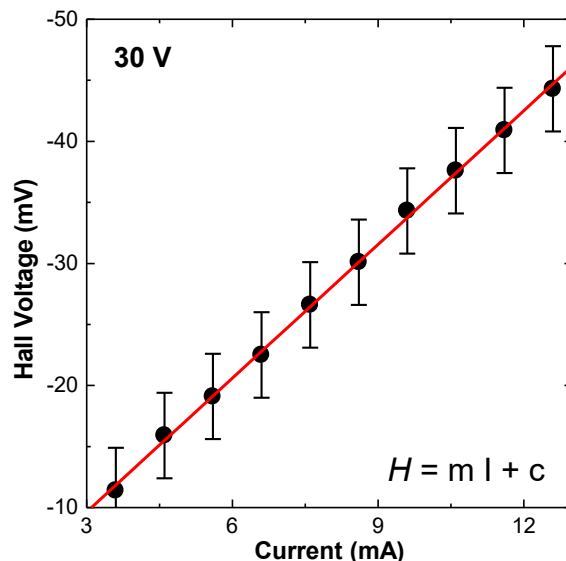
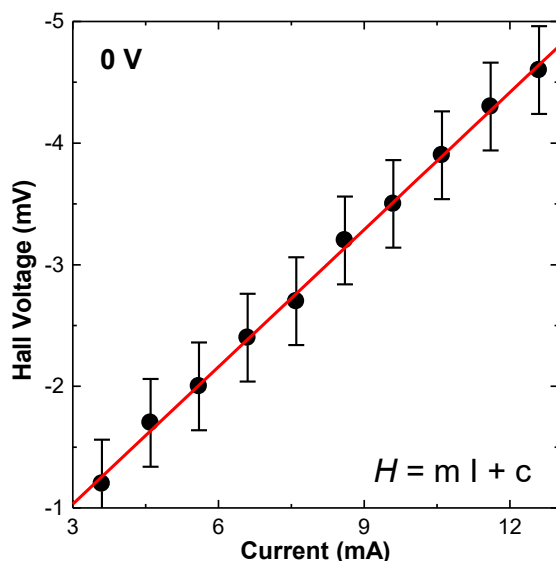


Figure 3: Hall voltage versus current plot. The error bar represents the standard error. (This data is taken from the set up at CDP, TU, Kirtipur)

CALCULATION:

By using the relation

$$R_H = \text{slope} \times \frac{t}{B} \quad \& \quad R_H = \frac{1}{ne}$$

$$\Rightarrow \text{Charge carrier density}(n) = \frac{1}{R_H e}$$

Here slope should be calculated from best fit plot (given below)

$$R_H = \dots\dots\dots \text{cm}^3/\text{coulomb}$$

$$n = \dots\dots\dots \text{cm}^{-3}$$

$$\mu_n (\text{or } \mu_p) = \dots\dots\dots \text{volt}^{-1} \text{sec}^{-1}$$

RESULT:

ERROR ANALYSIS:

DISCUSSION:

SECOND PART

Design and study use of n- & p- type materials to apply as fluxmeter probe.

Discuss with your group to make it and finally consult your teacher.

Reference:

1. Kittel C. – **Introduction to solid state physics**, 8th ed., John wiley& Sons (2005).

EXPERIMENT 5

Study the magnetic susceptibility of given diamagnetic and paramagnetic substances

AIM OF THE EXPERIMENT

After performing this experiment students will understand

1. Magnetic susceptibility χ of a given paramagnetic (e.g., FeCl_3) and diamagnetic solution (e.g., water) for a specific concentration.
2. Meaning and importance of mass susceptibility

APPARATUS REQUIRED:

- | | |
|--------------------------------------|-----------------------------|
| 1. Electromagnet | 4. Search Coil |
| 2. Quincke's tube or (U- shape tube) | 5. Travelling Microscope |
| 3. Fluxmeter | 6. Hall Probe |
| | 7. Ferric Chloride Solution |

THEORETICAL BACKGROUND

When a substance is placed within a magnetic field, it is magnetized. Most materials can be classified as diamagnetic, paramagnetic or ferromagnetic according to their behavior in external magnetic. Diamagnetic substances are magnetized feebly in opposite to the magnetizing field and so susceptibility is small and negative. Paramagnetic substances are magnetized feebly in the direction of magnetizing field. Susceptibility is small and positive. Ferromagnetic substances are magnetized strongly in the direction of magnetizing field and so susceptibility is large and positive. Quincke's devised a simple method to determine the magnetic susceptibility (χ), of a paramagnetic solution by observing how the liquid rises up between the two pole pieces of an electromagnet. In this experiment an aqueous solution of Ferric Chloride Solution (FeCl_3) is kept in the narrower part of a Quincke's tube. The narrower part is placed in a nearly uniform magnetic field while the wider part is far removed from the field. On activating the field with current the meniscus in the narrower part will rise if the solution paramagnetic and will fall if it is diamagnetic. A Hall probe determines the relationship between the current and the applied field. The magnetic susceptibility is given by

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

where M is magnetization and H is the magnetic field and it is a dimensionless quantity and is positive for the Paramagnetic substances.

Energy of magnetic field in the absence of substance $U_1 = \frac{1}{2} \mu_0 \int H^2 dv$

Energy of magnetic field in the presence of substance $U_2 = \frac{1}{2} \int \mu_0 \mu_r H^2 dv$

$\mu_r = 1 + \chi$ and χ is susceptibility. Gain in energy when the substance is placed in magnetic field

$$(U) = U_2 - U_1 = \frac{1}{2} \mu_0 \int (\mu_r - 1) H^2 dv$$

$$= \frac{1}{2} \mu_0 \int \chi H^2 dv$$

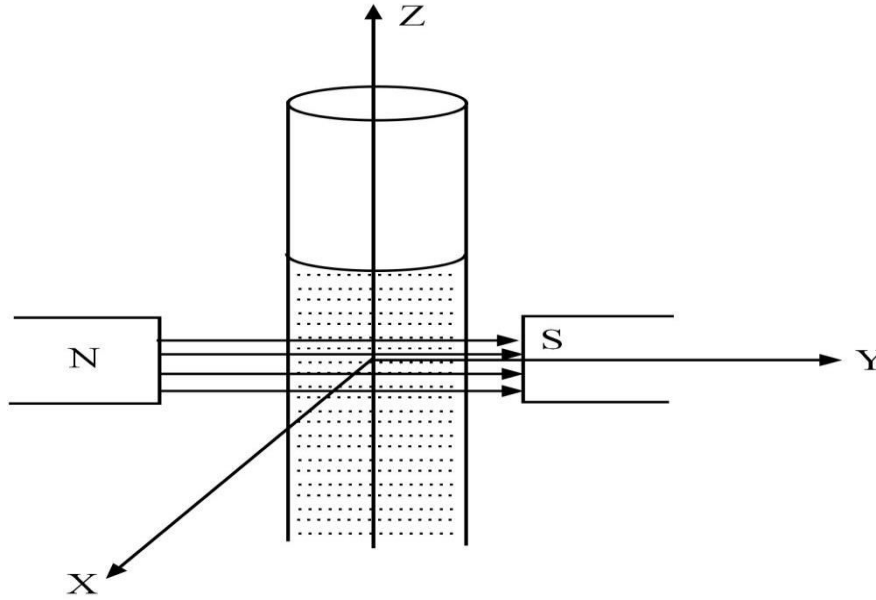


Fig. 1: Sketch of the experimental set up

Considering the magnetic field H along y -direction, its gradient along z -direction and supposing the field to be uniform along x - y plane

$$F_x = 0, F_y = 0 \text{ and so } F = F_z = -\frac{1}{2} \mu_0 \int \chi \frac{\partial H^2}{\partial z} dv$$

$$\frac{\partial H^2}{\partial z} dv = \frac{d\partial}{\partial z} A dz = A dH^2$$

$$\text{Therefore, } F = F_z = -\frac{1}{2} \mu_0 \chi_m A \int_H^0 dH^2 = \frac{1}{2} \mu_0 \chi_m A H^2$$

Under the action of force F the liquid is raised inside the tube until it's balanced by the weight of the liquid itself. If h is the height of the liquid raised and ρ is the density.

$$\text{So } F = mg = \rho g h A$$

$$\text{At equilibrium, } \vec{F}_{\text{upward}} = \vec{F}_{\text{downward}}$$

$$\frac{1}{2} \mu_0 \chi A H^2 = \rho g h A$$

$$\chi = \frac{2 \rho g h}{\mu_0 H^2}$$

$$\text{Mass susceptibility } (\chi_m) = \frac{\text{molar susceptibility}}{\text{density}} = \frac{\chi_m}{\rho}$$

$$\text{Therefore, } \chi_m = \frac{\chi}{\rho} = \frac{2 g h}{\mu_0 H^2} = \frac{2 g \mu_0 h}{B^2}$$

Instead of Quinck's tube, U-shaped tube is used the height is replaced by $2h$, $\chi_m = \frac{4 g \mu_0 h}{B^2}$

$$\chi_{\text{molar}} = \chi_m \times \text{molecular weight}$$

PROCEDURE:

1. Measured the strength of magnetizing field between the poles pieces of the electromagnet by using search coil and calibrated flux meter.
2. Measured the various values of current I passing through the magnetizing coil of the electromagnet. Calculate the value of magnetizing field H for each value of current .
3. Dissolve a weighed quantity of hydrous salt ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$), say 20 gms in water to make up 100 c.c. of solution.
4. Thoroughly clean the Quincke's or U-shape tube and fill it with 20% solution of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ and insert the narrow limb of the U-tube vertically between the pole pieces of electromagnet.
5. Now switch on the current and note the value of current. Again bring horizontal cross wire of the microscope on the liquid meniscus and note the reading.
6. Repeat the experiment for different values of magnetizing current. It is preferable to use the same values of current for which magnetic field have been calculated.
7. Take observations for a number of different values of concentration (10, 15, 20 and 25% FeCl_3) and Water.



Fig. 2: Experimental set up for Quicke's or U-Shape tube

OBSERVATION

a division of Vernier scale = b division of main scale

1 division of Vernier scale = $\frac{b}{a}$ division of main scale

Vernier constant = 1 division of main scale – 1 division of Vernier scale

$$= \left(1 - \frac{b}{a}\right) \times \text{value of 1 Main scale division}$$

\therefore Vernier Constant (V.C.) =

Table 1: Measurement of Magnetic Field

No. of obs	Current (Ampere)	Magnetic field	
		In Gauss	In Tesla
1			
2			
3			
4			
5			

Table 2: For 10% concentration of FeCl₃

No. of obs	Current (Ampere)	Initial Reading			Final Reading			$h = h_1 - h_2$ (cm)
		M.S	V.S×V.C	Total(h_1)	M.S	V.S×V.C	Total(h_2)	
1								
2								
3								
4								
5								
6								

$$\chi_m = \frac{2g\mu_0 h}{B^2} = \dots\dots\dots$$

Table 3: For 15% concentration of FeCl₃

No. of obs	Current (Ampere)	Initial Reading			Final Reading			$h = h_1 - h_2$ (cm)
		M.S	V.S×V.C	Total(h_1)	M.S	V.S×V.C	Total(h_2)	
1								
2								
3								
4								
5								
6								

$$\chi_m = \frac{2g\mu_0 h}{B^2} = \dots\dots\dots$$

Table 4: For 20% concentration of FeCl₃

No. of obs	Current (Ampere)	Initial Reading			Final Reading			$h = h_1 - h_2$ (cm)
		M.S	V.S×V.C	Total(h_1)	M.S	V.S×V.C	Total(h_2)	
1								
2								
3								
4								

5								
6								

$$\chi_m = \frac{2g\mu_0 h}{B^2} = \dots\dots\dots$$

Table 5: For 25% concentration of FeCl₃

No. of obs	Current (Ampere)	Initial Reading			Final Reading			$h = h_1 - h_2$ (cm)
		M.S	V.S×V.C	Total(h_1)	M.S	V.S×V.C	Total(h_2)	
1								
2								
3								
4								
5								
6								

$$\chi_m = \frac{2g\mu_0 h}{B^2} = \dots\dots\dots$$

Table 6: For Water

No. of obs	Current (Ampere)	Initial Reading			Final Reading			$h = h_1 - h_2$ (cm)
		M.S	V.S×V.C	Total(h_1)	M.S	V.S×V.C	Total(h_2)	
1								
2								
3								
4								
5								
6								

$$\chi_m = \frac{2g\mu_0 h}{B^2} = \dots\dots\dots$$

EXPECTED PLOTS:

(make plots for each concentrations and best fit these plots for the slope)

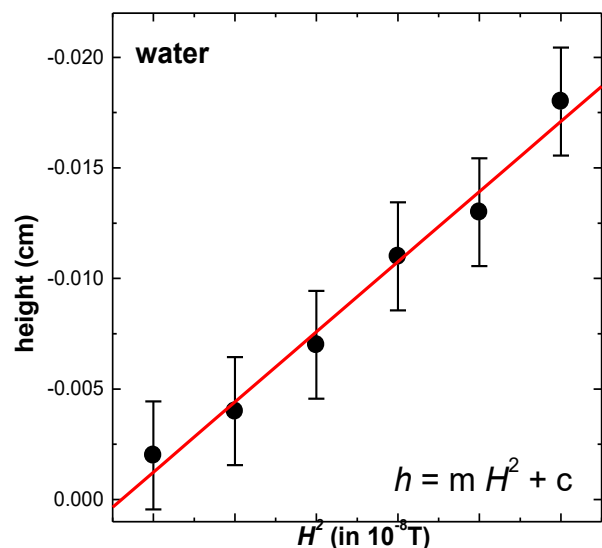
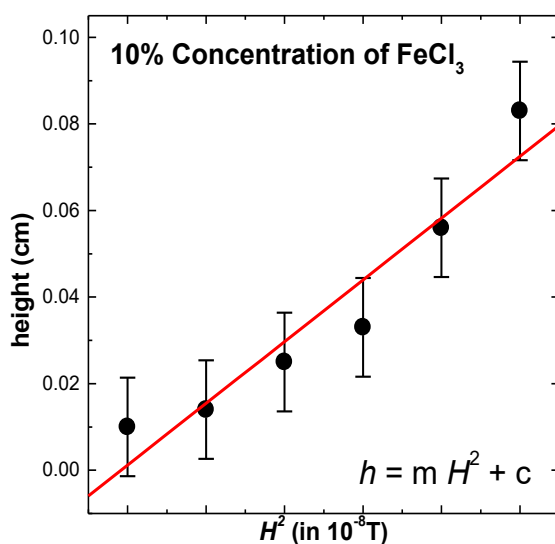


Figure 3: Height versus H^2 plot. The error bar represents the standard error. (This data is taken from the set up at CDP, TU, Kirtipur)

ERROR ANALYSIS:

We have, $\chi_m = \frac{2g\mu_0 h}{B^2}$

$$\Delta\chi_m = \chi_m \left[\left(\frac{\Delta h}{h} \right)^2 + 2 \left(\frac{\Delta B}{B} \right)^2 \right]^{\frac{1}{2}}$$

=

RESULT:

DISCUSSION:

References:

1. Arora C.L. B.Sc. Practical Physics, S. Chand and Company Ltd. (2010).

EXPERIMENT 6

Lattice Dynamics: (a) Study the monoatomic lattice vibration. Hence obtain the cut-off frequency of the given materials. (b) Study the diatomic lattice vibrations and determine the optical band gap

Aim of the Experiment

The following experiments may be performed with the help of this setup:

1. Study of the dispersion relation for the mono-atomic lattice-Comparison with theory.
2. Determination of the cut-off frequency of the mono-atomic lattice.
3. Study of the dispersion relation for the di-atomic lattice – ‘acoustical mode’ and ‘optical mode’ energy gap. Comparison with theory.

Theory:

Lattice dynamics is an essential component of any postgraduate course in Physics, Engineering Physics, Electronic Engineering and Material Science. In particular it is essential for understanding the interaction of electromagnetic waves and crystalline solids. In present setup, mono-atomic and diatomic lattices are stimulated using the transmission line having ten identical sections of LC resonant circuit. The dispersion relation for electrical analogue of the mono-atomic lattice is

$$\omega^2 = \frac{2}{LC}(1 - \cos \theta)$$

and dispersion relation for electrical analogue of diatomic lattice is

$$\omega^2 = \frac{1}{L} \left(\frac{1}{C} + \frac{1}{C_1} \right) + \frac{1}{L} \left[\left(\frac{1}{C} + \frac{1}{C_1} \right)^2 - \frac{4 \sin^2 \theta}{CC_1} \right]^{\frac{1}{2}}$$

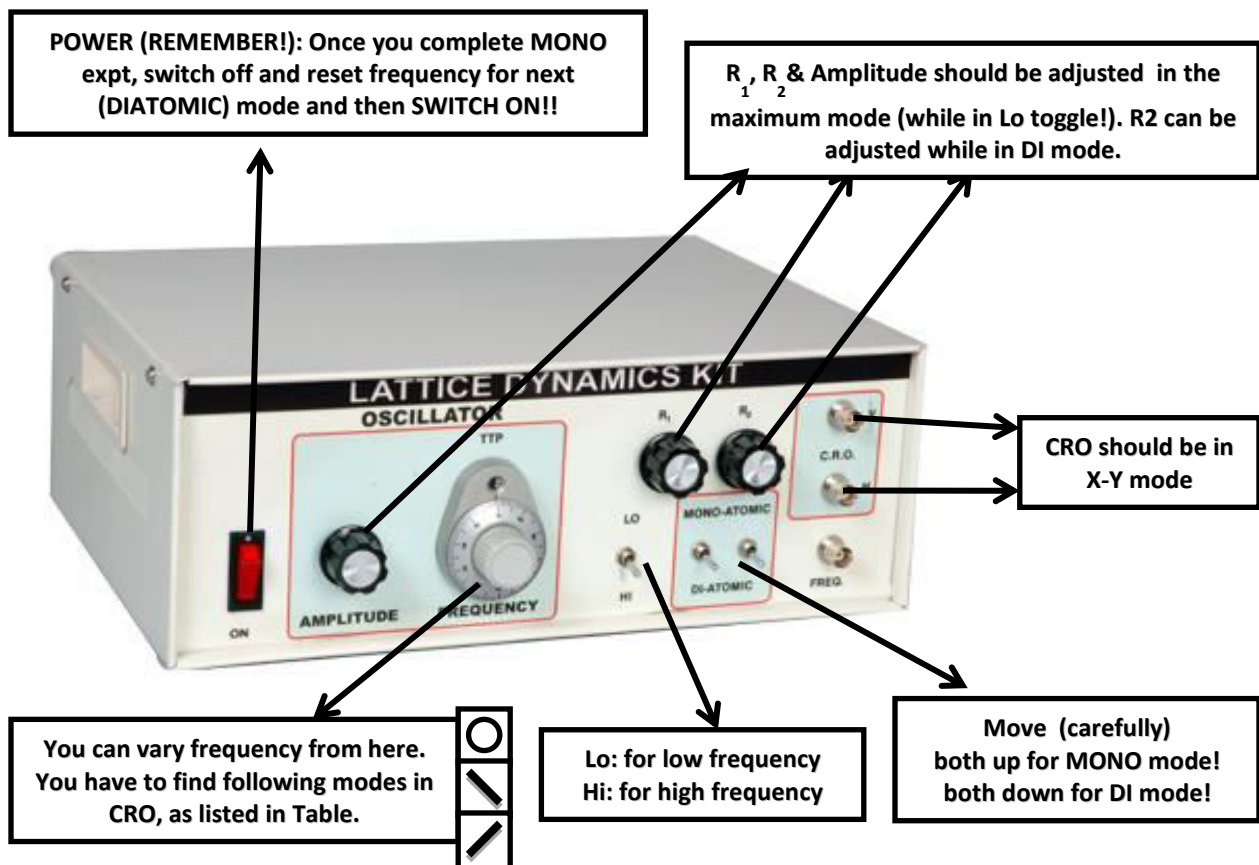
With the help of the simple and user friendly setup the phase difference between the input and output wave is measured at different frequencies and tabulated.

Then a graph of the experimental value and the theoretical value is plotted and compared.

Lattice Dynamics Kit

Lattice Dynamics Kit consists of the following parts:

It consists of an Audio oscillator with amplitude control and facility to vary the frequency from 0.9 KHz to 90 KHz. It has built in power-supply and output stage to match the impedance of simulated lattice. Another part of Lattice Dynamic Kit consists of transmission line, which simulates one-dimensional mono-atomic and di-atomic lattices. The only additional equipment needed is a General purpose C.R.O. Figure 1 shows the kit.



OBSERVATION & CALCULATION

In the Lattice dynamics Kit, we have $L = \dots\dots\dots H$ and $C = \dots\dots\dots mF$. So for theoretically, for electrical analog circuit,

$$f = \frac{1}{2\pi} \sqrt{\frac{4}{LC}} = \dots$$

Table 1: Monoatomic Lattice

SN	CRO Position	n_θ (in degree)	Dial Reading	Frequency calculated	Frequency calculated
1	/	0			
2	O	90			
3	/	180			
4	O	270			
5	/	360			
6	O	450			
7	/	540			
8	O	630			
9	/	720			
10	O	810			
11	/	900			
12	O	990			
13	/	1080			

14	O	1170			
15	/	1260			
16	O	1330			
17	/	1440			

Table 2: Diatomic Lattice

SN	CRO Position	n_θ (in degree)	Dial Reading	Frequency calculated (KHz)	Frequency calculated (KHz)
1	/	0			
2	O	90			
3	/	180			
4	O	270			
5	/	360			
6	O	450			
7	/	540			
8	O	630			
9	/	720			
10	O	810			
11	/	900			
12	O	990			
13	/	1080			
14	O	1170			
15	/	1260			
16	O	1330			
17	/	1440			

PLOTS: (The data for these plots are taken from the CDP experimental set up)

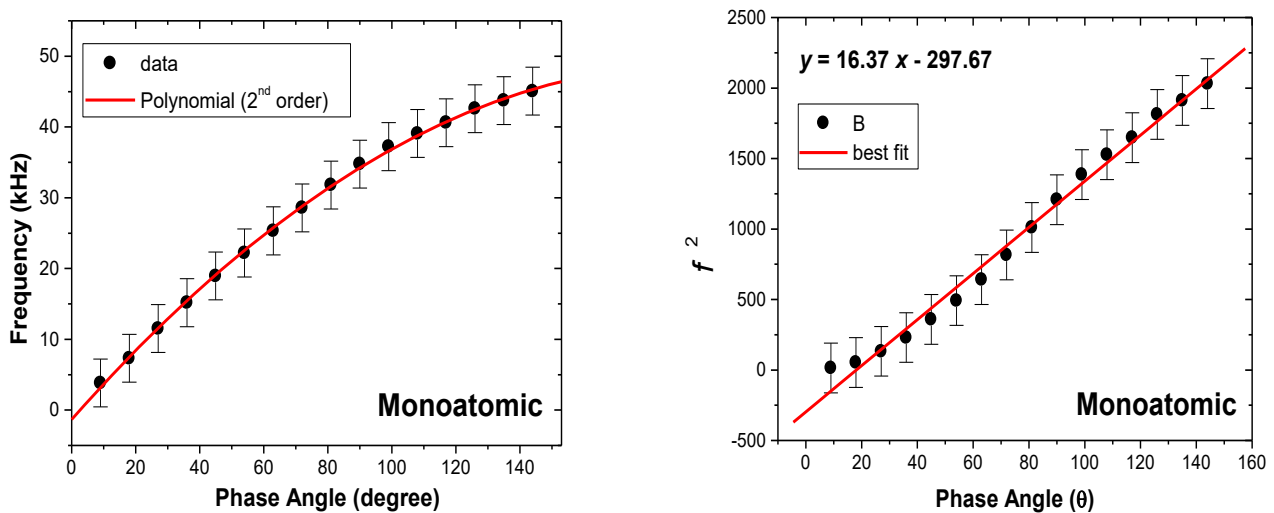


Figure 3: Monoatomic lattice. The best fit line and equation is shown. The error bar represent the standard error of the distribution.

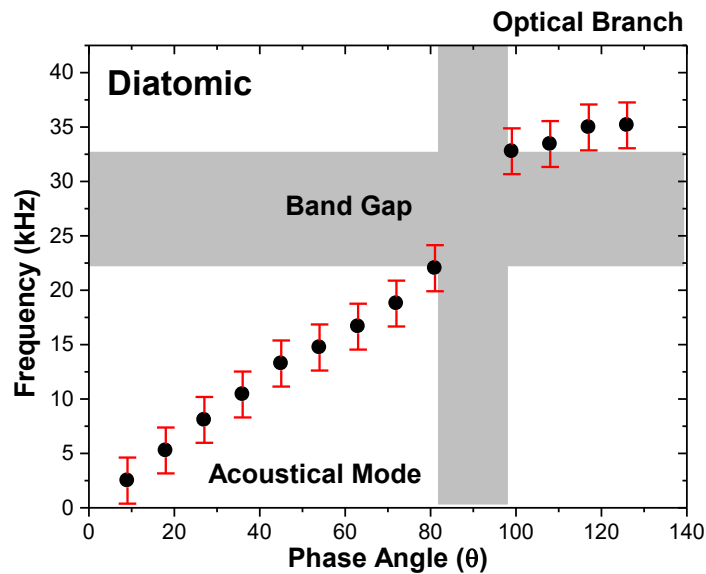


Figure 3: Diatomic lattice. The error bar represent the standard error of the distribution.

ERROR ANALYSIS

Estimate chi-square distribution by taking calculated and observed values frequencies for both mono and diatomic cases. You need to calculate chi-square value and chi-square probability and interpret your result.

RESULT

Summarize your result

DISCUSSION

Discuss your result

EXPERIMENT: 1

STUDY THE TRI-STATE LOGIC (TSL) CIRCUIT AND HENCE VERIFY ITS TRUTH TABLE

APPARATUS REQUIRED:

Power supply (+5V)
Transistor (BC547)
Diodes (IN4007)
Resistors (10k Ω , 1k Ω , 4.7 k Ω , 100 Ω)
Connecting wires
Bread board
Multimeter

PREREQUISITE:

RTL, TTL, DCTL, current hogging, open collector output, noise margins, ECL, TSL, wired-OR, totem-pole output.

WORKING PRINCIPLE:

Normal logic circuits have two states- LOW and HIGH. Output of such circuits is found either LOW or HIGH. However, in tri-state logic circuits which are used in complex digital systems like microcomputers and microprocessors, the output of the circuit has been found three states-LOW, HIGH and third state (high impedance state) rather than LOW and HIGH. So, these types of circuit are known as tri-state logic (TSL) circuits.

These TSL circuits are widely used in digital systems to overcome the following difficulties:

- Totem-pole outputs cannot be connected together because of very large current drain from the supply and consequent heating of the ICs used which may get damaged the ICs.
- Open collector output can be connected together with a common collector resistor connected externally. These causes the problems of loading and speed operation.

These circuits are ideally suited for bus connection.

The symbol of TSL is shown if Fig.1, its circuit in Fig.2 and its truth is given in Table 1.

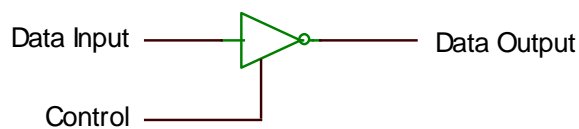


Fig.1: Logic symbol of a TSL inverter

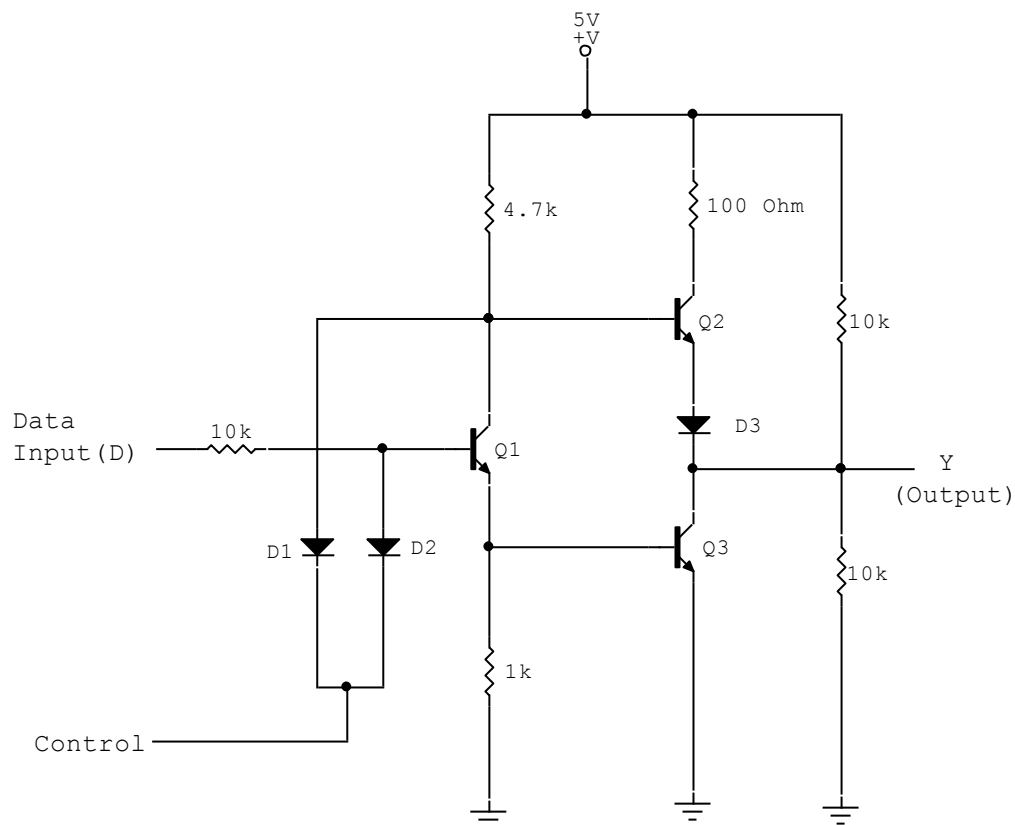


Fig.2: Tri-state logic circuit.

Table 1: Truth table of TSL circuit

Control (C)	Data input (D)	Data output (Y)	Remarks
0	0	High-Z	Open state or high impedance state
	1	High-Z	Open state or high impedance state
1	0	1	HIGH
	1	0	LOW

When control bit is low the diodes D1 and D2 conduct, transistors Q1, Q2 and Q3 remain cut-off. So the circuit acts as open state or high impedance state. In this case +V drops through resistors 10 k Ω and 10 k Ω , hence output found half of supplied voltage (+V/2). When control (D) is high and data input is low the transistor Q3 cut in and the output (Y) found HIGH. And when D is HIGH and control is also HIGH, all the three transistors Q1, Q2 and Q3 cut in and diode D3 conducts which gives Y LOW. In this way, using this circuit we get three state of output and verifies truth Table. 1.

PROCEDURE:

1. Choose the suitable valued transistors, diodes and resistors.
2. Construct the circuit as shown in Fig. 2 on a bread board.
3. Check the power supply with the help of multimeter whether it is +5V or not.
4. Multimeter of small least count minimizes noise margins so set multimeter's knob.
5. Switch on the power supply.
6. Take all possible combinations of input data and control, and measure corresponding output voltages using multimeter.
7. Verify the truth table i.e. Table. 1.

PRECAUTIONS:

1. Higher value of supply voltage may get damaged the circuit.
2. Be careful, when connecting of N- and P- junctions of diodes and, emitter, base and collector of transistors.
3. Knowledge of working voltage of transistors Q1, Q2 and Q3 helps to remove current hogging in the circuit.

REFERENCES:

1. I. J. Nagrath, Electronics, Analog and digital, Prentice Hall of India Private Limited New Delhi, 2001.
2. R. P Jain, Modern Digital Electronics, 2nd edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.
3. Donald D. Leach and Albert Paul Malvino, Digital Principles and Applications, 5th edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.

EXPERIMENT: 2

TO STUDY THE MULTIPLEXER AND VERIFY ITS TRUTH TABLE

APPARATUS REQUIRED:

Power supply (+5V)

ICs: 7404, 7410, 7420.

Timer: 555

Bread board and Connecting wires

Resistors (10 k Ω , 1 k Ω , 4.7 k Ω , 100 Ω)

Capacitors: 0.1 μ C and 0.01 μ C

Oscilloscope and Multimeter

PREREQUISITE:

4-1 multiplexer, 16-1 multiplexer, NOT gate, NAND gate, control signal, timer, astable multivibrator.

WORKING PRINCIPLE:

The multiplexer is special combinational circuit that is one of the most widely used standard circuits in digital design. The term 'multiplex' means many into one. By applying control signal, we can steer any input to the output. The input selected is controlled by a set of control signal. Fig. 1 shows the block diagram of a multiplexer with n-input signals, m-control signals and one output signal.

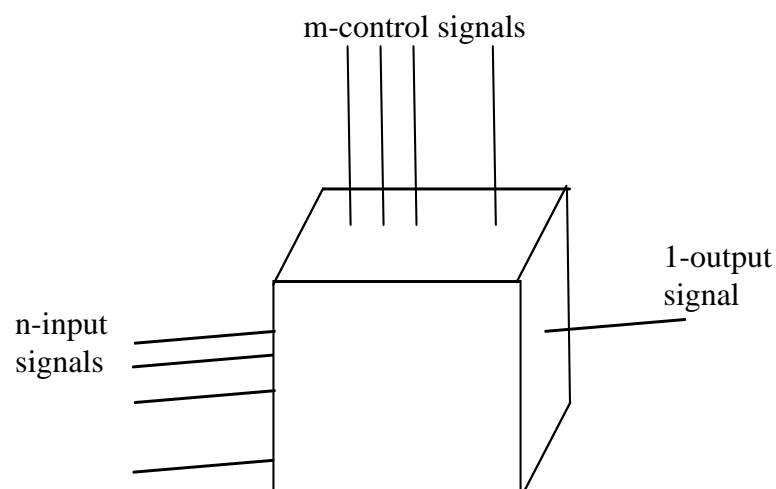


Fig. 1. Block diagram of multiplexer

For selecting one out of n inputs for connection to the output a set of m -select inputs (control signal) is required where $2^m = n$. Depending upon the digital signals applied at the control signal, one out of n data sources is selected and transmitted to signal output channel. Multiplexer is necessary if there is a requirement to connect multiple. For example: phone, computer etc.

The experimental circuit for 4 to 1 multiplexer is shown in Fig. 2.

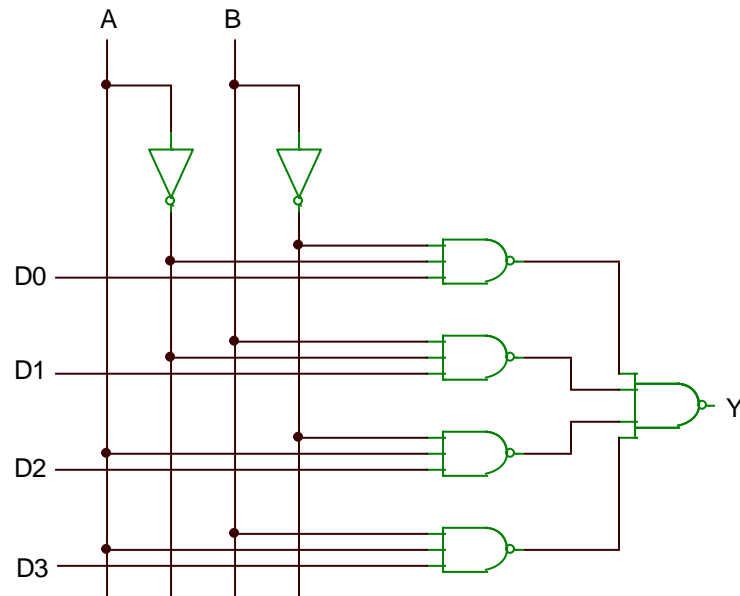


Fig.2: 4-1 multiplexer.

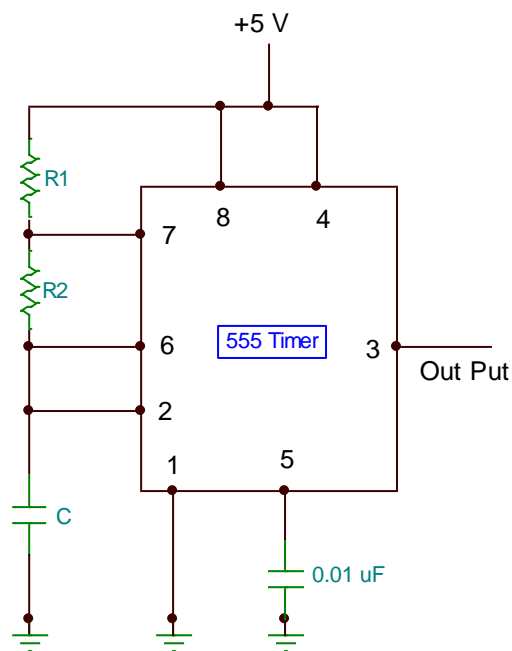


Fig 3. Astable multivibrator.

In Fig. 2, A and B are control signals, D0, D1, D2 and D3 data inputs and Y is output. When both A and B control signals are LOW, both pin 1 and pin 2 of upmost NAND gates become HIGH. So its output depends upon D0. Therefore A = 0, B = 0 select D0 output.

Then the output can be expressed in the form of

$$Y = \bar{A} \bar{B} D0 + \bar{A} B D1 + A \bar{B} D2 + A B D3$$

Thus when A = 0, B = 0; Y = D0

A = 0, B = 1; Y = D1

A = 1, B = 0; Y = D2

A = 1, B = 1; Y = D3

Table 1: Truth table 4-1 multiplexer.

Control		Data input				Data output
A	B	D0	D1	D2	D3	Y
0	0	D0	X	X	X	D0
0	1	X	D1	X	X	D1
1	0	X	X	D2	X	D2
1	1	X	X	X	D3	D3

PROCEDURE:

1. Choose the suitable ICs (7404, 7410 and 7420) and set up the circuit as shown in Fig. 2.
2. Construct the astable multivibrator circuit using 555 timer on bread board as in Fig. 3.
3. Select suitable value of resistors and capacitor for square wave form of output from pin 3 of timer circuit.
4. Check the output of power supply (+5V) and supply it to the circuits.
5. Observe the output of timer circuit which is used as input data in multiplexer.
6. Observe the truth table for different value of input and corresponding output and verify the truth table you observed as shown in Table 1. above.
7. Trace the input and output wave form and calculate it (in V) from oscilloscope.

PRECAUTIONS:

1. Check the supplied voltage before used to circuit otherwise other than required value may damage the circuit and components.
2. Clear about identification of pins of ICs. If desired pin is not connected, it may get damaged ICs and finally circuit.
3. When data input is given D0, connect all the other data input line to either low or high but do not left unconnected.

REFERENCES:

1. I. J. Nagrath, Electronics, Analog and digital, Prentice Hall of India Private Limited New Delhi, 2001.
2. R. P Jain, Modern Digital Electronics, 2nd edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.
3. Donald D. Leach and Albert Paul Malvino, Digital Principles and Applications, 5th edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.
4. S. L. Gupta and V. Kumar, Handbook of Electronics; Pragati prakashan, 2009.

EXPERIMENT: 3

DESIGN AND STUDY THE 1-BIT DIGITAL COMPARATOR CIRCUIT

APPARATUS REQUIRED:

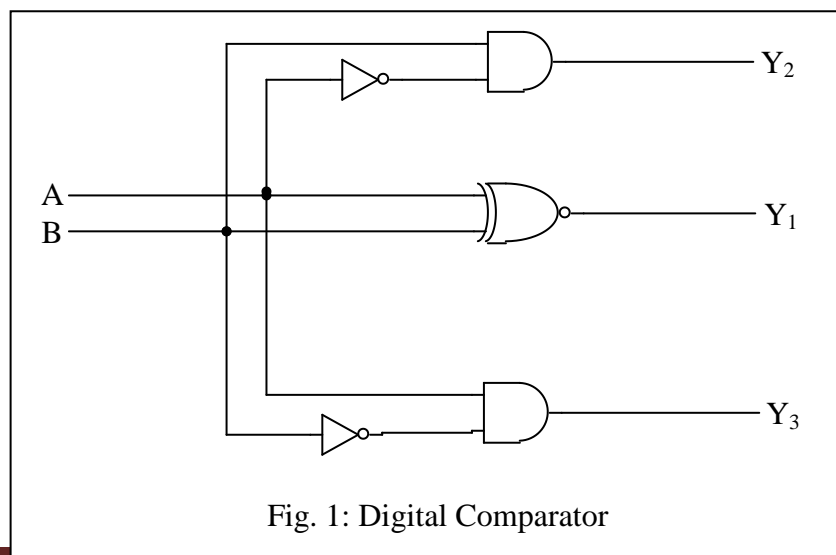
Power supply (+5V)
ICs: 7400, 7404, 7420
Timer: 555
Connecting wires
Bread board
Resistors (10k Ω , 1k Ω)
Multimeter
Transistors (BC547)

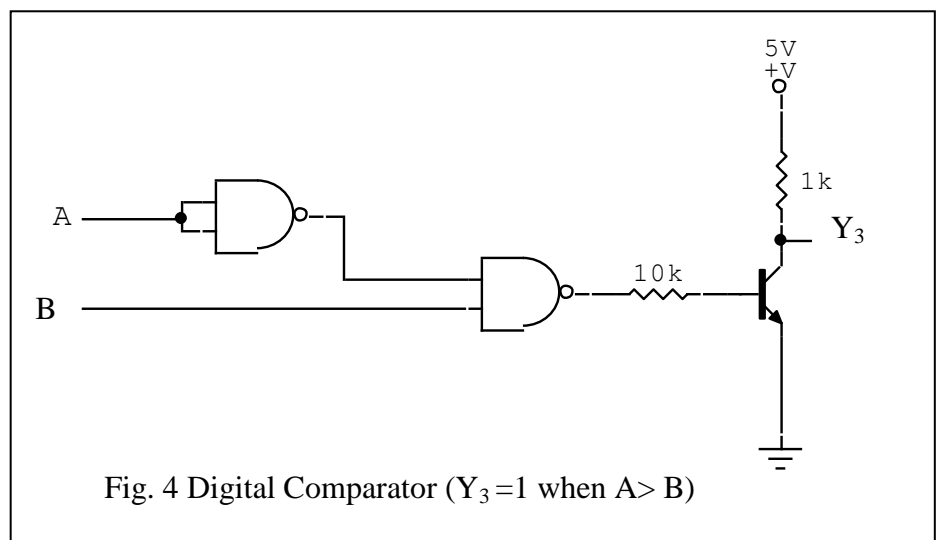
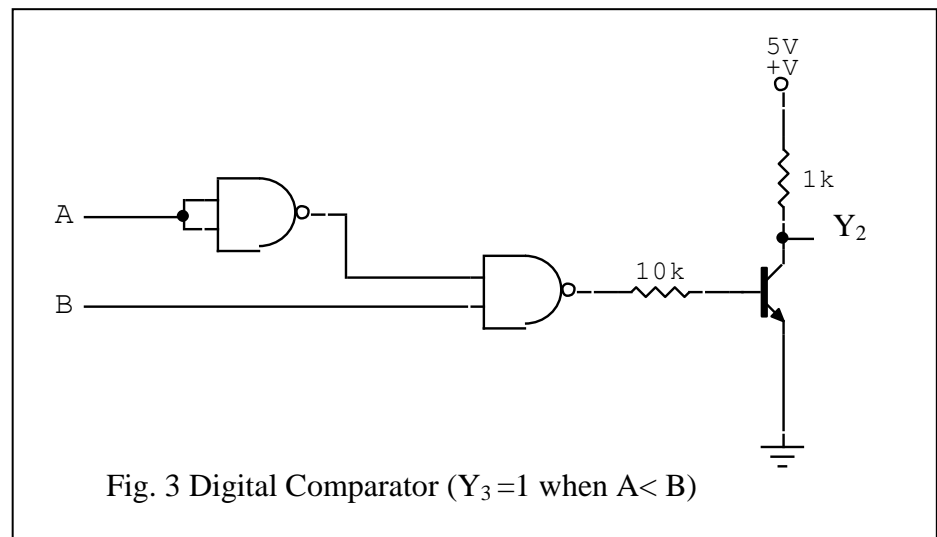
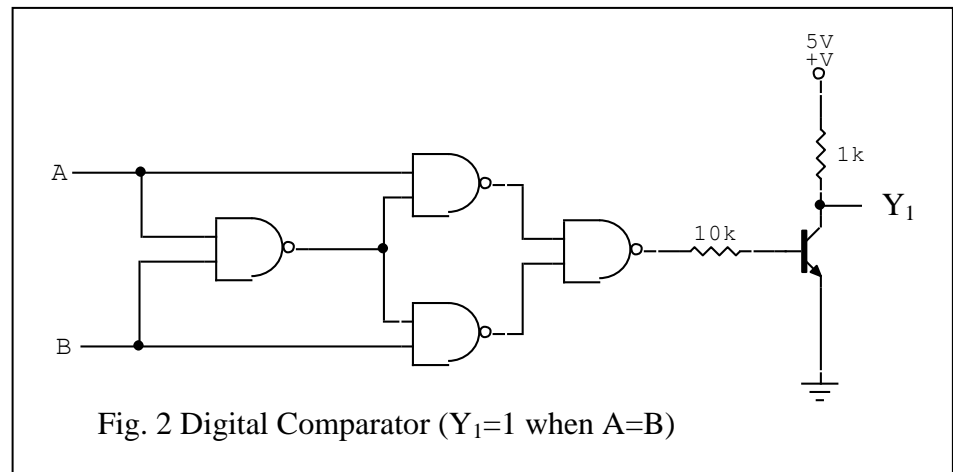
PREREQUISITE:

NOT, AND, NAND Ex-OR gates, equality checker.

WORKING PRINCIPLE:

A 1-bit digital comparator circuit is shown in Fig. 1. The circuit can be designed using ICs 7410, 7404, 7400 or TTL Ex-OR gate and AND gates. Digital comparator is used to check the transmission of binary numbers and to find the error in transmitting message (digital numbers).





Truth table for 1-bit digital comparator is shown in Table 1.

Table. 1.

A	B	Y_1	Y_2	Y_3
0	0	1	0	0
0	1	0	1	0
1	0	0	0	1
1	1	1	0	0

PROCEDURE:

1. Connect the circuits as shown in Fig. 2, Fig. 3 and Fig. 4 on bread board for different cases of comparator.
2. Switch on the power supply and measure the output of the supply using multimeter.
3. Draw a truth table for outputs of circuits corresponding to different inputs and verify the table with Table. 1.
4. Check the $Y_1 = 1$ for $A = B$ case, $Y_2 = 1$ for $B > A$ and $Y_3 = 1$ for $A > B$ cases.

PRECAUTIONS:

1. Proper numbered ICs should be used.
2. Operation of all gates of ICs should be checked separately before making circuit using the ICs.
3. Supplied power supply should not exceed than the operating voltage of IC used.

REFERENCES:

1. I. J. Nagrath, Electronics, Analog and digital, Prentice Hall of India Private Limited New Delhi, 2001.
2. S. L. Gupta and V. Kumar, Handbook of Electronics, Pragati prakashan, 2009.
3. Donald D. Leach and Albert Paul Malvino, Digital Principles and Applications, 5th edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.

EXPERIMENT: 4

TO STUDY THE DEMULTIPLEXER AND VERIFY ITS TRUTH TABLE

APPARATUS REQUIRED:

Power supply (+5V)

ICs: 7404, 7410

Timer: 555

Connecting wires

Bread board

Resistors (10k Ω , 1k Ω , 4.7 k Ω , 100 Ω)

Capacitors: 0.1 μ C and 0.01 μ C

Oscilloscope, Multimeter

PRE-REQUISITE:

Multiplexer, Demultiplexer (1-4 & 1-16), NOT gate, NAND gate, Control signal, Timer, Astable multivibrator.

WORKING PRINCIPLE:

The demultiplexer is opposite of multiplexer which means 'one into many'. By applying special control signal we can steer the input signal into one of the many outputs. Fig. 1 shows the block diagram of a demultiplexer with one input line, m-control signal and n-output lines.

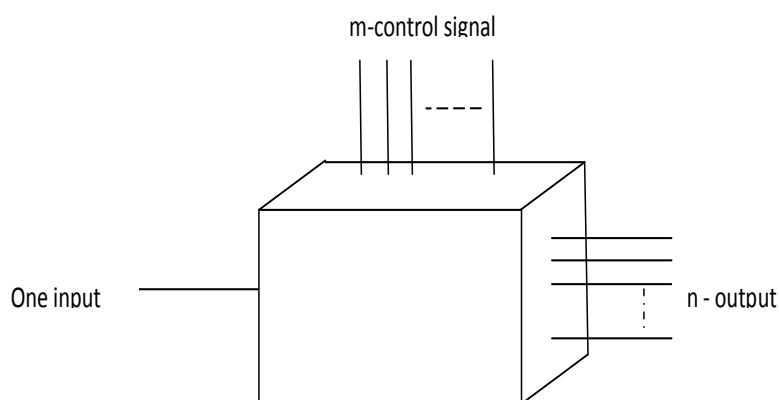


Fig. 1 Block diagram of demultiplexer

In order to select the data into one of n-output lines, a set of m-control signals is required where $2^m = n$.

Depending upon the digital signal applied at the control signal, input data is appeared into one out of n-input lines. A demultiplexer if we have to connect multiple output devices one at a time to a certain system. For example, if we have to retrieve data from CPU of a computer to monitor, printer, modem etc, then we have to connect demultiplexer between CPU and different output devices.

Here we are going to design 1 to 4 demultiplexer circuit using ICs 7404 and 7410 shown in Fig. 2 below.

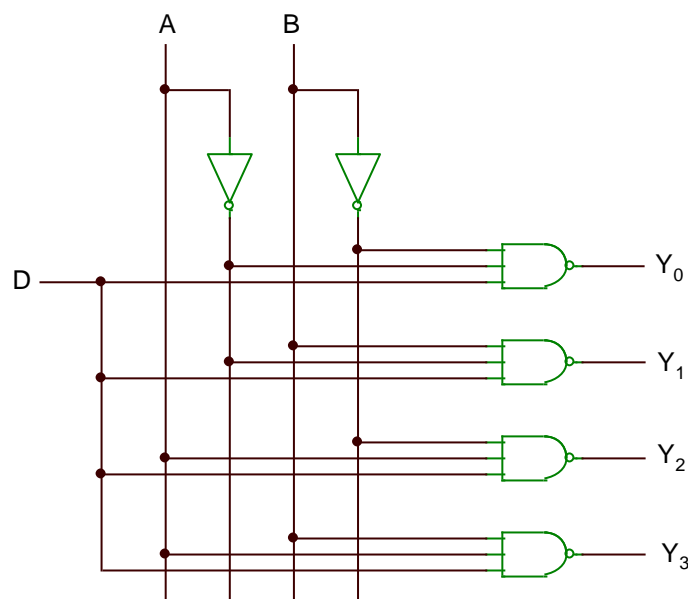


Fig.2: 1-4 demultiplexer.

In the Fig. 2, A and B are control signals, D is the data input which is used output of astable multivibrator, and Y_0 , Y_1 , Y_2 and Y_3 are output lines observed on oscilloscope screen.

Using Boolean algebra,

$$Y_0 = \overline{A} \overline{B} \overline{D} = A + B + \overline{D}$$

$$Y_1 = \overline{A} \overline{B} D = A + \overline{B} + \overline{D}$$

$$Y_2 = \overline{A} B \overline{D} = \overline{A} + B + \overline{D}$$

$$Y_3 = \overline{A} B D = \overline{A} + \overline{B} + \overline{D}$$

The truth table for 1-4 multiplexer is as shown in Table. 1 below.

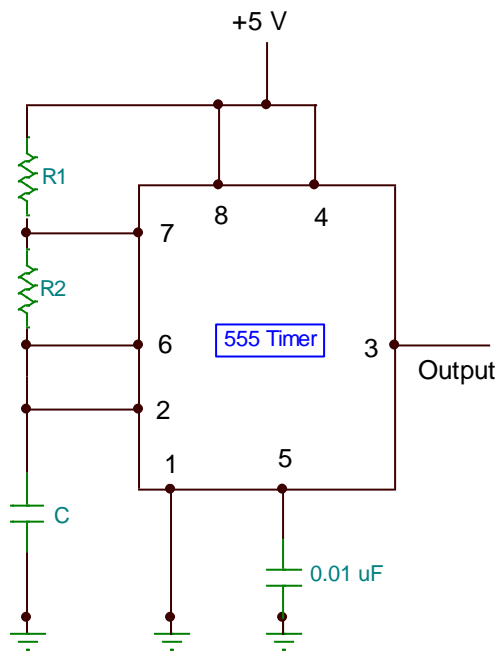


Fig 3. Astable multivibrator.

Table 1: Truth table for 1-4 demultiplexer.

Control signal		Data	Output			
A	B	D	Y_0	Y_1	Y_2	Y_3
0	0	D	\bar{D}	0	0	0
0	1	D	0	\bar{D}	0	0
1	0	D	0	0	\bar{D}	0
1	1	D	0	0	0	\bar{D}

PROCEDURE:

1. Connect the circuit for astable multivibrator using 555 timer as in Fig. 3.
2. Then construct the circuit as in Fig. 2 and use output of astable as input for demultiplexer.
3. Observe and trace the output of demultiplexer on oscilloscope (calculate in V) and check whether the truth table is verified or not.

PRECAUTIONS:

1. Proper numbered ICs should be used.
2. Operation of all gates of ICs should be checked separately before making circuit using the ICs.
3. Used power supply should not exceed than the operating voltage of IC used.

REFERENCES:

1. I. J. Nagrath, Electronics, Analog and digital, Prentice Hall of India Private Limited New Delhi, 2001.
2. R. P Jain, Modern Digital Electronics, 2nd edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.
3. Donald D. Leach and Albert Paul Malvino, Digital Principles and Applications, 5th edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.
4. S. L. Gupta and V. Kumar, Handbook of Electronics; Pragati prakashan, 2009.

EXPERIMENT: 5

DESIGN AND STUDY THE 1- BIT MEMORY CIRCUIT

APPARATUS REQUIRED:

Power supply (+5V)

ICs: 7400, 7404, 7410, 7420

Connecting wires

Bread board

PREREQUISITE:

Combinational circuit, memory circuit, flip-flop, register, counter, trigger, bistable multivibrator, static RAM, dynamic RAM.

WORKING PRINCIPLE:

In combinational logic circuit, the output of the system at a given instant of time depends only upon the value of inputs at the same moment. This means that these types of circuit systems are said to have no memory. But memory circuit or sequential digital circuit, the generated outputs of circuit are not only dependent of the present states of inputs but also on the past history of these inputs. A flip-flop, register and counters are used as memory elements. RAM and ROM are also memory circuits.

Here, we are going to design and study the circuit of Random Access Memory (RAM) which consists of storage registers each of which is identified with an address and can be written into or readout under a control command. RAM is volatile memory. The circuit diagrams and truth table are shown below.

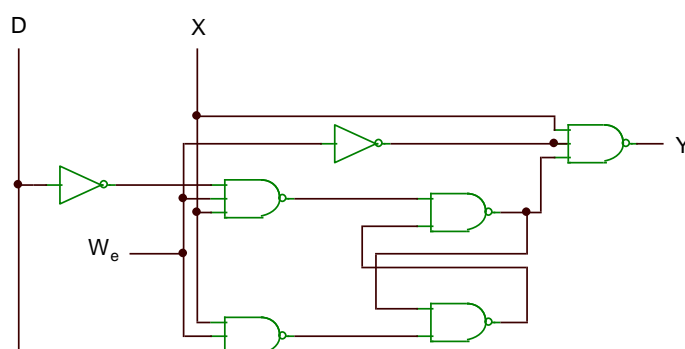


Fig. 1 Circuit of RAM

Table 1: Truth table for RAM

Address (X)	Write Enable (W _e)	Data input (D)	Output (Y)	Comments
0	x	x	1	Disable No address
1	1	0	1	Write '0' False output
1	0	x	0	Read '0' True output
1	1	1	1	Write '1' False output
1	0	x	1	Read '1' True output

PROCEDURE:

1. Connect the circuit as in Fig. 1. with proper number of ICs and their pin numbers.
2. Use +5V power supply to the circuit and draw a truth table different set of inputs and corresponding outputs.
3. Check the table you found verifies the truth Table. 1.

PRECAUTIONS:

1. Proper numbered ICs should be used.
2. Operation of all gates of ICs should be checked separately before using the ICs.
3. Power supply should not exceed than the operating voltage of ICs.

REFERENCES:

1. I. J. Nagrath, Electronics, Analog and digital, Prentice Hall of India Private Limited New Delhi, 2001.
2. S. L. Gupta and V. Kumar, Handbook of Electronics; Pragati prakashan, 2009.
3. Donald D. Leach and Albert Paul Malvino, Digital Principles and Applications, 5th edition, Tata McGraw-Hill Publishing Company Limited New Delhi, 2002.

EXPERIMENT: 6

TO DESIGN THE DECIMAL-TO-BINARY CODED DECIMAL (BCD) ENCODER AND VERIFY THE CONVERSION

MATERIALS REQUIRED:

Power supply: +5V

Equipment: Multi-meter, Project board

Resistors: $1K\Omega$ - 4

Semiconductors: Diode (IN4007) - 15

Miscellaneous: Jumpers

PREREQUISITE:

Binary number system, Code, Encoder etc.

THEORY:

Binary coded decimal (BCD) is a way to express each of the decimal digits, 0 through 9, with a 4-bit binary code. The BCD code is a weighted code. The most significant bit has a weight of 8, and the least significant bit has a weight of only 1. This code is more precisely known as the *8421 BCD code*. The 8421 part of the name gives the weighting of each place ($2^3, 2^2, 2^1, 2^0$) in the 4-bit code. There are several other BCD codes that have other weights for the four place values. Because the 8421 BCD code is most popular, it is customary to refer to it simply as the BCD code. The Table-1 gives the BCD code for one decimal digit.

BCD representation is not the same as binary representation and it is clear that BCD is wasteful of bits, since each 4-bit group could represent sixteen numbers (0000 through 1111) but in this code only ten of these are used. The six code combinations (1010 through 1111) are not used or invalid in the BCD code. However, BCD is ideal because it is very easy to convert between decimal and BCD. To express any decimal in BCD, simply replace each decimal with the appropriate 4-bit binary code.

An encoder converts an active input signal into a coded output signal. The Decimal-to-BCD encoder converts an active decimal into BCD code.

Decimal symbol	BCD code			
	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Table-1: The BCD code

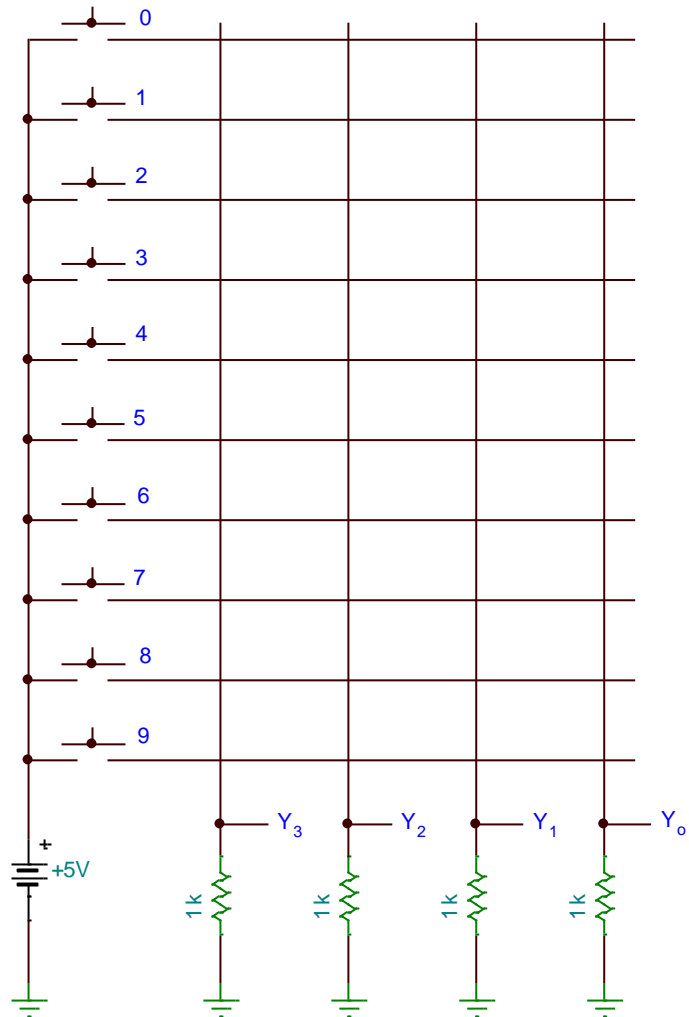


Figure-1: Decimal-to-BCD encoder

PROCEDURE:

1. Check the power supply and note the exact value of its output.
2. Check each diode before use.
3. Construct the circuit as shown in Fig-1 (*Note: always check the direction of the diode*).
4. Measure the voltage across each resistance for each corresponding decimal digit and record in Table. (*Note: never press more than one switch simultaneously*)

PRECAUTIONS:

1. During circuit connection, always check anode and cathode of the diode.
2. During observations, never presses more than one switch simultaneously
(*limitation of the experiment*).

REFERENCES:

1. Digital Principles and Applications: A. P. Malvino, D.P. Leach. 4th ed.
2. Digital Fundamentals: T.L. Floyd. 8th ed.