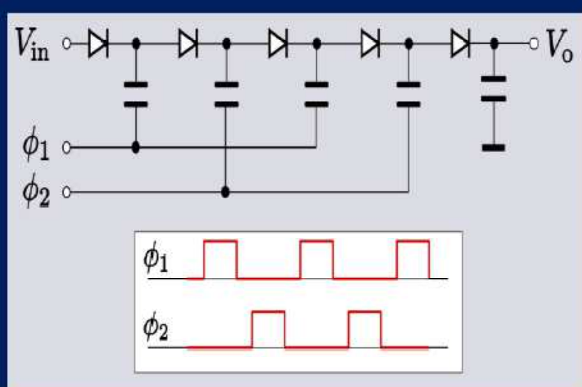
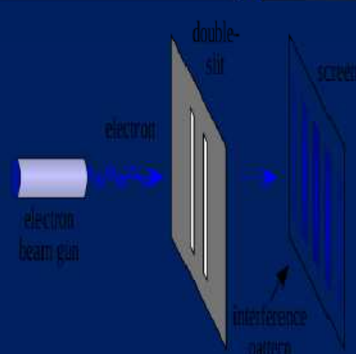
BSCPH304

B. Sc. III YEAR
Experimental Physics III





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Experimental Physics III

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Course 10: Experimental Physics III Course code: BSCPH304

Credit: 3

Experiment 1: To draw the characteristics of vacuum diode valve

Structure

1.1 **Object**:

After performing this experiment, you should be able to

- What are vacuum tubes specially diode
- Working of diode
- How characteristics of diode valve is drawn

1.2 **Introduction:**

Diode valve is a vacuum tube having two electrodes namely plate and cathode inside evacuated glass tube. It works on the principle of thermionic emission. For the proper use of the diode valve plate is kept at high potential with respect to cathode. When cathode of diode is heated by passing current in it, the cathode emits electrons. These electrons are collected by plate, which is at positive potential with respect to cathode. Electrons flow from cathode to plate, thus plate current flows in plate circuit. As plate voltage increases the plate current also increase. The current in circuit is controlled by plate and grid potentials. The plate current flows in the circuit only when plate is positive potential with respect to cathode and direction of flow of electron is always from cathode to plate never plate to cathode. Because of this unidirectional flow of current, diode is called 'diode valve'.

At constant temperature of cathode the variation of plate current with the plate voltage is non linear and plate current is controlled by space charge. The current is called space charge limited current. When the temperature of cathode is increased, more electrons are emitted from cathode hence increase in saturated plate current .

1.3 **Apparatus Used:**

The diode valve, 6.3 volt heating filament (cathode), high tension source for plate (around 250V), voltmeter (0-250V) , milliammeter (0-10 mA) and Rheostat (100Ω), connection wires.

1.4 **Theory and Formula Used**:

Diode valve is two electrode namely plate and cathode. When cathode of the diode valve is heated, the electrons are emitted from the surface of cathode. The number of electrons emitted depends on temperature of the cathode. The first group of emitted electrons gathers in the space surrounding the cathode. It exerts repealing electrostatic force to next emitted electrons, which therefore start to return to cathode. Their return is however prevented by next group of emitted electrons. Thus the dense cloud of electron is formed in space around cathode. This electron cloud is called space charge. This space charge repeals the further emitted electron. When plate is given small positive potential, some of the electrons near the plate is attracted by plate and constitute current. If we further increase plate potential, the plate current also increases. This current only depends on space charge, plate potential and independent of temperature of cathode.

When plate voltage is increased, the plate current also increases. This variation is not linear, and current is called space limited plate current. If the plate voltage is further increases, the current become maximums called saturated current. This happens when plate voltage is enough high to attract all electrons emitted by cathode. At this stage, the saturated current can only increased by increasing temperature of cathode. This saturated current is called temperature limited current.

1.5 About apparatus:

Diode valve is a vacuum tube having two electrodes namely plate and cathode inside evacuated glass tube as shown in figure 1. Cathode, which serve as source of electrons is an indirectly heated oxide-coated nickel cylinder. Cathode is heated indirectly by insulated heater filament enclosed within it. The plate is also hollow cylinder made of nickel, molybdenum or iron and surrounds the cathode.
The apparatus in the experiment is a simple electric circuit as shown in figure 2. The triode valve have three electrode 6V battery is connected to the electric bulb with rheostat. For the measurement of current and voltage the DC Voltmeter (0-10V) & DC ammeter (0-1 A) are connected.

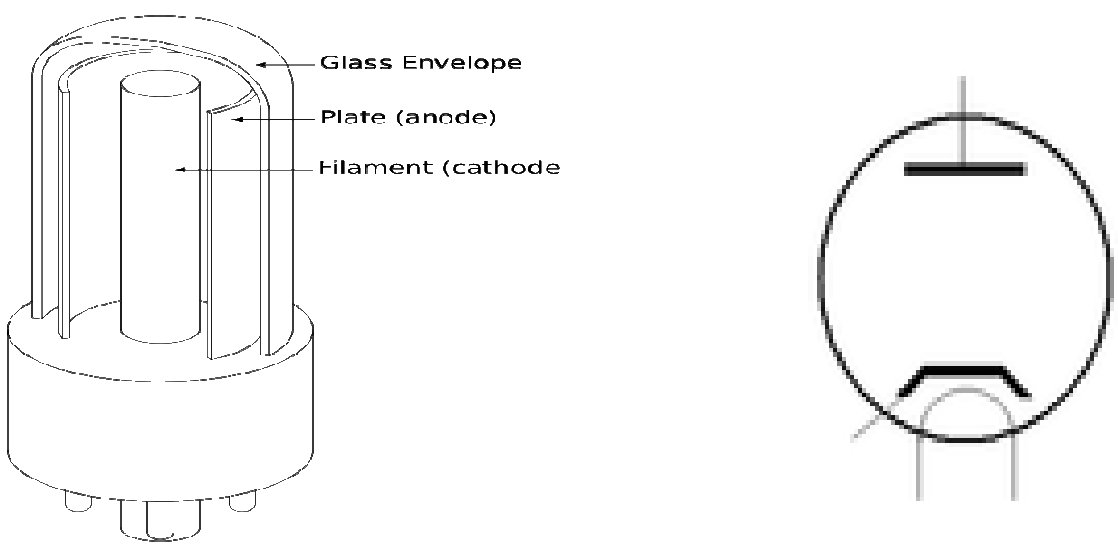

Figure 1

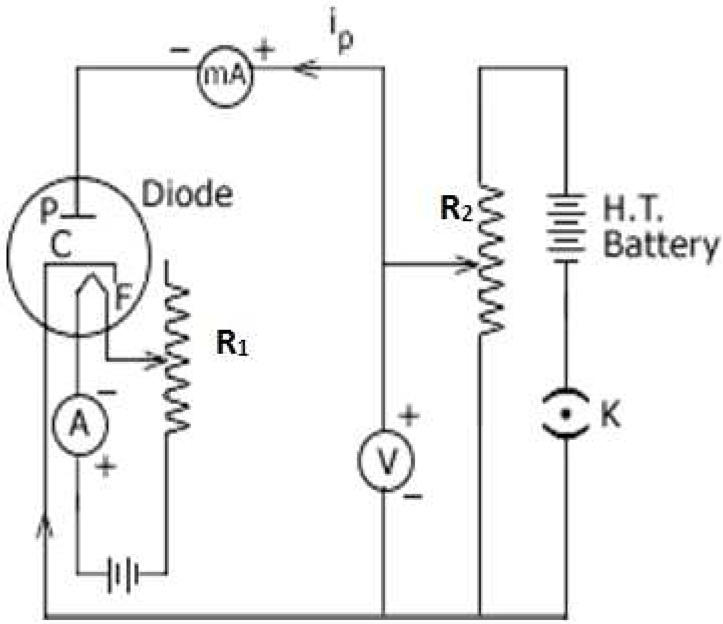

Figure 2

1.6 Procedure:

For plate characteristics, perform the experiment in following steps.

1. Make electrical connection as shown in figure 2.
2. With the help of rheostat R_2 adjust to minimum plate voltage.
3. Note down the plate current in milliamter.
4. Now increase the plate potential in the steps (say in 2V step) and read the corresponding plate current in milliamter.
5. Draw the graph between plate voltage and plate current, which is called plate characteristics of diode.

1.7 Observation:

Table1.For plate Voltage and plate current

1	Plate Voltage V_p Volt	Plate current I_P mA
2		

3		
4		
5		
6		
7		
8		
9		
10		

1.8 **Result:** The characteristics curve of diode valve is presented in the given graph.

1.9 Precaution and source of error:

1. Sensitive voltmeter and sensitive ammeter sould be used.
2. The direction about maximum plate voltage and filament voltage by manufacturer should be strictly followed.
3. Initiallty the plate voltage should be adjusted at minimum value.
4. There should not be any fluctuation on the power.
5. Reading are taken only for space charge limited region.
6. The graphs should drawn smothly.

1.10 Summary:

1. A vacuum diode is a device which works on the principle of thermionic emission.
2. Diode has two electrode namely plate cathode.
3. There is unidirectional flow of current i.e. from plate to cathode.
4. When plate potential increases, the plate current also increase.
5. Plate current is of order milliampares flows in circuit.

1.11 Glossary

` Vacuum Tube: It is evacuated glass tube in which electrodes are fitted.

Filament: It is a cathode, which emits electrons after heating.

Rheostat: It is used to vary potential.

Rectifier: It the device which convert AC into DC.

Resistance: Obstruction to the flow of current.

1.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
3. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
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6. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
7. *https://en.wikipedia.org.*

1.13 Viva-voce questions:

Question1. Define the process of thermionic emission?

Answer: When metal filament is heated, it emits electron from its surface. The phenomenon of emission of electrons by heating is called thermionic emission.

Question2. Why the diode is called diode valve?

Answer: The device is called diode as there are two electrodes namely plate and cathode. The flow of current in the device is unidirectional from plate to cathode. The current flows when plate is positive potential with respect to cathode, not when plate is negative potential with respect to cathode.

Question3. Define space charge?

Answer. When cathode of diode valve is heated, the electron emitted from surface of cathode. These emitted electrons make cloud in space between cathode and plate and they repeal the further emitted electron from cathode. This cloud of negatively charged is called space charge.

Question4. What is the use of diode valve?

Answer: Diode valve is used in rectification i.e. it covert AC signal to DC signal.

Question5. What is saturated current and how it is increased?

Answer: On increasing plate voltage the plate current increase. But when plate voltage is sufficient high to attract all the electrons emitted by cathode i.e. rate of emission of electrons by cathode is equals the rate of attraction of electrons by plate, the plate current does not change by change of plate voltage. This maximum current is called saturated current. The saturated current can be increased by increasing temperature of cathode as that more electrons are available to flow.

Experiment 2: To draw characteristics of triode valve

Structure

2.1 Object:

After performing this experiment, you should be able to

- What is triode valve
- How current is controlled by two electrode i.e. grid and plate
- Use of triode valve
- Drawing of characteristics of triode valve

2.2 Introduction:

Triode valve is a vacuum tube having three electrodes namely plate, cathode and grid inside evacuated glass tube. It works on the principle of thermionic emission. For the proper use of the triode valve plate is kept at high potential with respect to cathode, and grid is given relatively low negative potentials. When cathode of triode is heated by passing current in it, the cathode emits electrons. The electron first emitted repels the other electrons which follow, so that cloud of electrons (space charge) is formed near cathode. If plate is given positive potential with respect to cathode, electrons flow from cathode to plate through the grid. Thus plate current flows in plate circuit. As plate voltage increases the plate current also increase. The function of grid is to remove space charge and control the flow of electron from cathode, so that the grid is given small negative potential respect to cathode.

The current in circuit is controlled by plate and grid potentials. Controlling current by grid and plate the triode valve is used as amplifier.

2.3 Apparatus Used:

The triode valve, 6.3 volt heating filament (cathode), high tension source for plate (around 250V), low tension source for grid (nearly 15V), two voltmeters i.e. voltmeter (0-20V) and voltmeter (0-250V) , milliammeter (0-1 mA) and Rheostat (100Ω),connection wires.

2.4 Theory and Formula Used:

Triode is three electrodes vacuum tube and it works on the principle of thermionic emission. The cathode is source of electrons, which when reaches plate constitute plate current. For the flow of plate current in plate circuit the plate voltage is given high positive potential and grid is given low negative potential with respect to cathode. The plate current in plate circuit is control by both plate potential and grid potential. As grid is more nearer relative to plate so grid is more efficient in controlling the current. By this virtue the triode can be used as amplifier.

For the proper use of triode as amplifier it is always useful to know the characteristics and constants of triode valve. Characteristics curve shows relations among plate-current, plate potential and grid potential. There are two important types of characteristics.

(I) Plate (or anode) characteristics: These are the curve showing variation of plate current i_p with plate voltage V_p at constant grid voltage V_g. We obtain plate characteristics by plotting graph between plate current i_p with plate voltage V_p at constant grid voltage V_g say for -2V and plots same for different grid potential -4V, -6V……. All the graphs show plate characteristics.

(II) Mutual characteristics: These are the graphs which are plotted with grid voltage V_g and plate current i_p at constant plate voltage V_p say at 150V. Same will be repeated for different plate voltage say for 200V, 250N…….

Formulas for determining constants of triode are as follows

Amplification Factor (μ): It is the ratio of a small change in plate potential to the change in grid potential in opposite direction under the condition that plate current remains constant. Thus

$$\mu = -\left(\frac{\partial V_p}{\partial V g}\right)_{i_p}$$

Plate resistance (r_p): It is define as ratio of small change of plate potential to the resulting change in plate current at constant grid potential.

$$r_p = -\left(\frac{\partial V_p}{\partial i_p}\right)_{V_g}$$

Mutual Conductance (g_m): It is define as ratio of small change of plate potential to the resulting change in plate current at constant grid potential.

$$g_m = -\left(\frac{\partial i_p}{\partial V_g}\right)_{V_p}$$

2.5 About apparatus:

Triode valve is a vacuum tube having three electrodes namely plate, grid and cathode inside evacuated glass tube as shown in figure 1. Cathode, which serve as source of electrons is an indirectly heated oxide-coated nickel cylinder. Cathode is heated indirectly by insulated heater filament enclosed within it. The cathode is surrounded by (wired mesh grid is surrounded by plate (hollow cylinder made of nickel, molybdenum or iron).

The apparatus in the experiment is a simple electric circuit as shown in figure 2. The triode valve have three electrode 6V battery is connected to the electric bulb with rheostat. For the measurement of current and voltage the DC Voltmeter (0-10V) & DC ammeter (0-1 A) are connected.

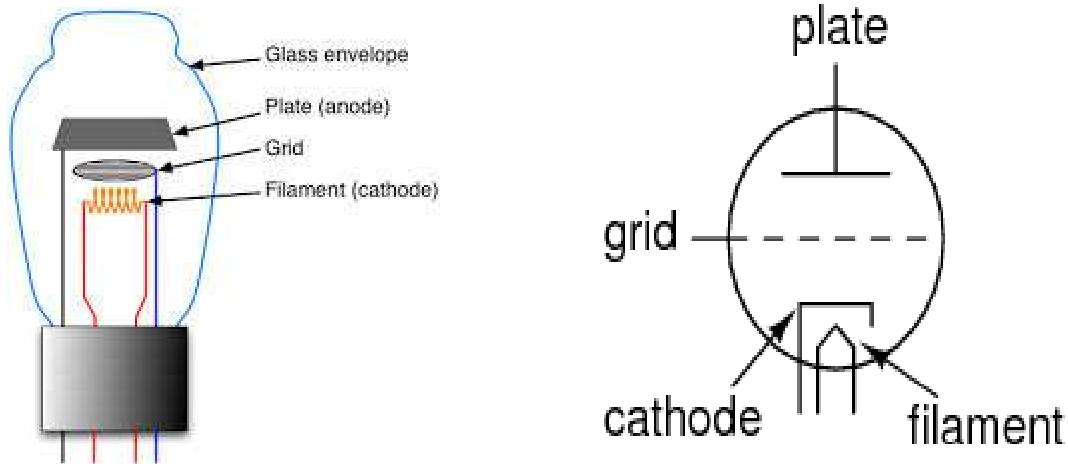


Figure 1

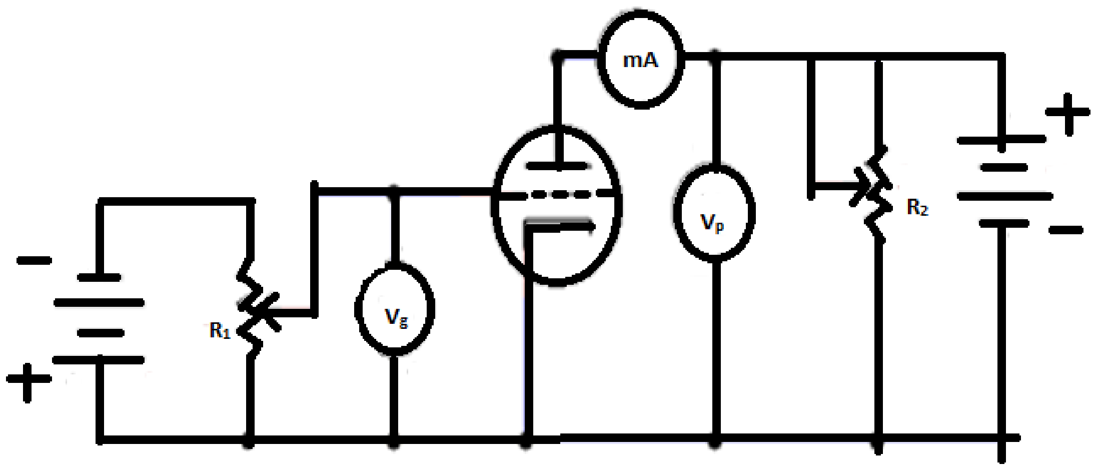


Figure 2

2.6 Procedure:

For plate characteristics, perform the experiment in following steps.

6. Make connection as shown in figure 2.
7. With the help of rheostat (by varying resistance R_2) adjust plate voltage say 20 V.
8. With the help of rheostat (by varying resistance R_1) adjust grid voltage say -2 V.
9. Note down the plate current in milliamter.
10. Now increase the plate potential in the steps (say in 5V step) and read the corresponding plate current in milliamter.

11. Draw the graph between plate voltage and plate current, which is called plate characteristics of triode.
12. Repeat the observations for the different grid potential as for -4V, -6V,....., and draw the graphs for same.

For mutual characteristics, perform the experiment in following steps.

1. With the help of rheostat (by varying resistance R_1) adjust plate voltage say 150 V.
2. With the help of rheostat (by varying resistance R_2) adjust grid voltage say -2 V.
3. Note down the plate current in milliamter.
4. Now increase the grid potential in the steps (say in 1V step) and read the corresponding plate current in milliamter.
5. Draw the graph between grid voltage and plate current, which is called mutual characteristics of triode.
6. Repeat the observations for the different plate potential as for 150V, 200V......., and draw the graphs for same.

2.7 Observation:

Table1.For plate characteristics

S. N.	Grid Potential V_g = -2V		Grid Potential V_g = -4V		Grid Potential V_g = -6V	
	Plate voltage Vp (V)	Plate current Ip (mA)	Plate voltage Vp (V)	Plate current Ip (mA)	Plate voltage Vp (V)	Plate current Ip (mA)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Table2. For mutual characteristics

S. N.	Plate Potential V_p = 150V		Prid Potential V_p = 200V		Prid Potential V_p = 250V	
	grid voltage Vg (V)	Plate current Ip (mA)	grid voltage Vg (V)	Plate current Ip (mA)	grid voltage Vg (V))	Plate current Ip (mA)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

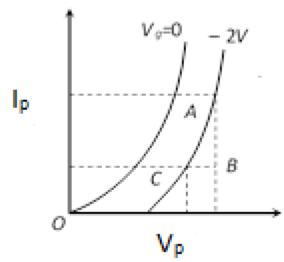
2.8 Calculation and Discussion:

(i) It is the ratio of small change in plate voltage to the change in plate current produced by it, the grid voltage remaining constant. From the graph 1

$$r_p = \frac{\Delta V_p}{\Delta I_p}, \text{ At constant } V_g$$

.

$$r_p = \frac{\Delta BC}{\Delta AB}$$



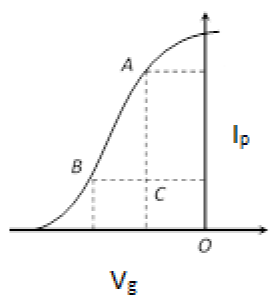
Graph 1

(ii) Mutual conductance or trans-conductance (gm)

It is defined as the ratio of small change in plate current (ΔI_p) to the corresponding small change in grid potential (ΔV_g) at constant V_p. From the graph 2

$g_m = \frac{\Delta I_p}{\Delta V_g}$ at constant plate voltage V_p

$$g_m = \frac{\Delta AC}{\Delta BC}$$



Graph 2

(iii) The value of amplification factor (μ) is calculated by following relation

$$\mu = r_p \times g_m$$

2.9 Result: The plate characteristics and mutual characteristics are presented in graph and tube constant are found as

Amplification Factor (μ) = …………

Plate resistance (r_p) = …………ohm

Mutual Conductance (g_m) = …………mhos

2.10 Precaution and source of error:

7. Sensitive voltmeter and sensitive ammeter sould be used.
8. The direction about maximum plate voltage, grid voltage and filament voltage by manufacturer should be strictly followed.

9. The graphs should drawn smothly.
10. There should not be any fluctuation on the power.
11. Plate voltage also changes for the change of grid voltage but it should be adjusted for constant value.
12. For determining plate constant, the straight part of the curve should be taken.

2.11 Summary:

6. A vacuum triode is a device which works on the principle of thermionic emission.
7. Triode has three electron namely plate, grid and cathode.
8. When plate potential increases, the plate current also increase and on increasing grid potential plate current decreases.
9. Current of order milliampares flows in circuit.
10. The resistance of triode valve is order of kilo-ohm.
11. Triode valve have relatively low amplification factor (μ).

2.12 Glossary

` Vacuum Tube: It is evacuated glass tube in which electrodes are fitted.

Filament: It is a cathode, which emits electrons after heating

Rheostat: It is used to vary potential

Amplifier: This raises the strength of weak signal.

Resistance: Obstruction to the flow of current.

2.13 References:

8. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
9. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
10. S.L.Gupta, V.Kumar A Hand book of electronics Pragati prakashan, Meerut.
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12. V.K.Mehta and Rohit Mehta,Principle of electronics S. Chand publication, Delhi.
13. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
14. *https://en.wikipedia.org.*

2.14 Viva-voce questions:

Question1. Define the process of thermionic emission?

Answer: When metal filament is heated, it emits electron from its surface. The phenomenon of emission of electrons by heating is called thermionic emission.

Question2.What is the construction of triode valve?

Answer: Triode valve is a vacuum tube having three electrodes namely plate, cathode and grid inside evacuated glass tube

Question3. What is the function of grid?

Answer. The function of grid is to influence the space charge and thus control the flow of current from cathode to plate. Due to more effectiveness for controlling current of grid than plate, triode is used as amplifier.

Question4.What is the space charge.

Answer: When cathode of diode valve is heated, the electron emitted from surface of cathode. These emitted electrons make cloud in space between cathode and plate and they repeal the further emitted electron from cathode. This cloud of negatively charged is called space charge.

Question5.What is the relation between constants of triode valve.

Answer: $\mu = r_p \times g_m$, symbols are in usual meaning.

Experiment 3: To draw the characteristics of tetrode valve

Structure

3.1 Object:

After performing this experiment, you should be able to

- What are vacuum tubes specially tetrode
- Working of tetrode
- How characteristics of tetrode is drawn
- What is use of tetrode

3.2 Introduction:

Due to disadvantages of low amplification factor, inter-electrode capacitance and undesirable feedback at low frequencies, the use of triode valve is limited. However this drawback can be overcome up to some limit by introducing a extra electrode in between plate and grid of triode valve. This extra electrode is called screen grid.

Tetrode is a vacuum tube having four electrode namely cathode, control grid, screen grid and plate. It works on the principle of thermionic emission. The tetrode is used as amplifier i.e. it raises the strength of weak signal.

3.3 Apparatus Used:

The tetrode valve, 6.3 volt heating filament (cathode), high tension source for plate (0-250V), low tension source (0-20V) voltmeter (0-250V) , milliammeter (0-10 mA) and Rheostat (100Ω), connection wires.

3.4 Theory and Formula Used:

When cathode of the tetrode valve is heated, the electrons are emitted from the surface of cathode. The number of electrons emitted depends on temperature of the cathode. Theses electrons are attracted by plate when given positive potential. Of course some of electrons will have sufficient energy to reach the plate even if plate is at zero potential with respect to cathode. When plate voltage is increased, the plate current also increases. This current is controlled by control grid which is at low negative potential.

The screen grid is kept at low positive potential with respect to cathode. The electrons emitted from cathode are accelerated by screen voltage while going from cathode to plate. Some of these electrons are attracted by screen producing screen current (very small Current) and most of electrons reach plate producing plate current.

There is screening effect on tetrode. When fast moving electrons strike on the surface of screen, these electrons knock out from screen. These electrons are called secondary electrons and they repeal the electrons coming from cathode hence reducing plate current. Due to this there comes negative resistance region (at low plate voltage) in which plate current decreases with increase of plate voltage. This is called negative resistance region.

When plate voltage is sufficiently higher than the screen voltage, the plate collects almost all the electrons from cathode.

3.5 About apparatus:

Tetrode valve is a vacuum tube having four electrodes namely plate, control grid, screen grid and cathode inside evacuated glass tube as shown in figure 1. Cathode, which serve as source of electrons is an indirectly heated oxide-coated nickel cylinder. Cathode is heated indirectly by insulated heater filament enclosed within it. The cathode is surrounded by control grid (wired mesh), and control grid by screen grid (wired mesh) and screen grid is surrounded by plate (hollow cylinder made of nickel, molybdenum or iron).
The apparatus in the experiment is a simple electric circuit as shown in figure 2. The tetrode valve has four electrodes. All the electrodes are given proper voltage. For the measurement of current and voltage the DC Voltmeter (0-250V), Voltmeter (0-150V) & DC ammeter (0-10 mA) are connected.

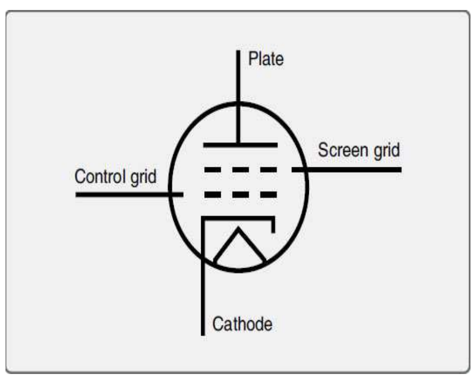

Figure 1

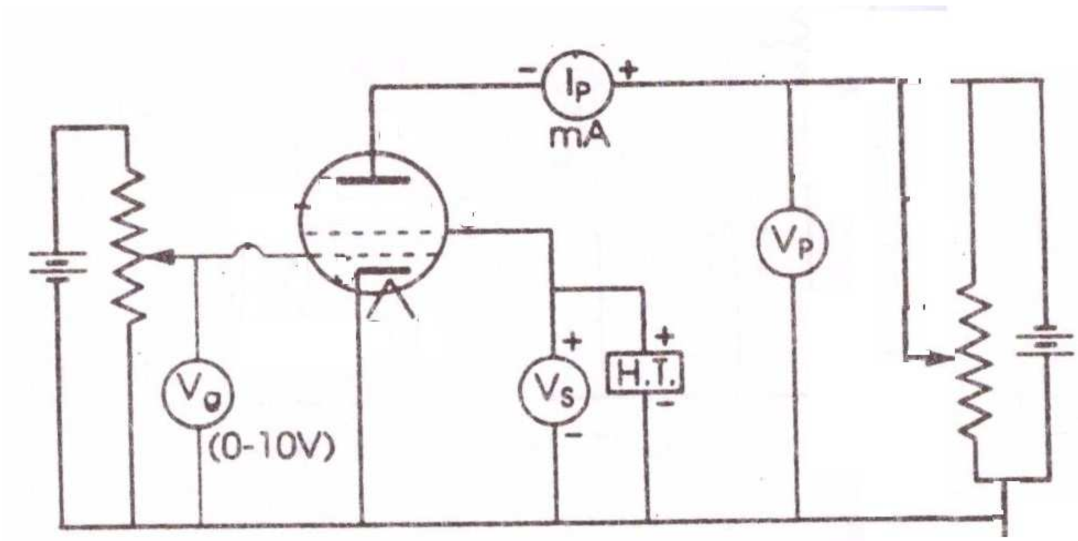

Figure 2

3.6 Procedure:

For plate characteristics, perform the experiment in following steps.

13. Make electrical connection as shown in figure 2.
14. Control grid is kept at 0V and screen voltage at 100V
15. With the help of rheostat RH plate voltage is increase from 0 to 250V.
16. Note down the corresponding plate current (I_p) and screen current (I_s) in milliamter.
17. Keep grid voltage at -2V, screen voltage 100V repeats the same procedure as describe above.

3.7 Observation:

Table1.For plate Voltage and plate current & screen current

SN	V_G = 0V				V_G = -2V			
	V_p volt	I_p mA	I_s mA	I_p+ I_s mA	V_p volt	I_p mA	I_s mA	I_p+ I_s mA

1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

3.8 Result: The characteristics curve of diode valve is presented in the given graph. From the graph we observe that

(1) When plate voltage is less than screen voltage, there is a reduction in plate current. This is due to emission of secondary electrons emitted from plate.
(2) At higher plate potential the plate current become independent of plate voltage for a particular value of control grid potential.

3.9 Precaution and source of error:

13. Sensitive voltmeter and sensitive ammeter sould be used.
14. The direction about maximum plate voltage and filament voltage by manufacturer should be strictly followed.
15. Initiallty the plate voltage should be adjusted at minimum value.
16. There should not be any fluctuation on the power.
17. The graphs should drawn smothly.

3.10 Summary:

12. A vacuum tetrode is a device which works on the principle of thermionic emission.
13. Tetrode has four electrodes namely plate, screen grid, control grid and cathode.
14. There is unidirectional flow of current i.e. from plate to cathode.

15. Current is of order milliampares flows in circuit.
16. When plate potential increases from 0V, the plate current decreases as electrons are attracted by screen. When plate voltage exceeds screen voltage, the plate current increases.
17. The plate current decreases on increasing plate voltage in some region of characteristics curve of tetrode valve. This region is called negative resistance region

3.11 Glossary

` Vacuum Tube: It is evacuated glass tube in which electrodes are fitted.

Filament: It is a cathode, which emits electrons after heating.

Rheostat: It is used to vary potential.

Amplifier: The device which increases strength of weak signal.

3.12 References:

15. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
16. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
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20. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
21. *https://en.wikipedia.org.*

3.13 Viva-voce questions:

Question1. Define the process of thermionic emission?

Answer: When metal filament is heated, it emits electron from its surface. The phenomenon of emission of electrons by heating is called thermionic emission.

Question2. Why the device is called tetrode?

Answer: The device is called tetrode as there are four electrodes namely plate, screen grid, control grid and cathode.

Question3. What is the function of grid?

Answer: (1). It overcomes the space charge effect.

(2). It reduces the interelectrode capacitance between control grid and plate.

Question4. What is secondary emission?

Answer: When the plate is less positive than screen grid, the secondary electrons produced by impact of high velocity electrons from cathode knock out electrons from surface of plate by striking it. This emission of electron is called secondary emission.

Question5. What is negative resistance?

Answer. In tetrode when the plate voltage is increased (less than screen voltage) the plate current decreases, as secondary electrons emitted by plate are attracted by screen.

Question6. What is the use of tetrode valve?

Answer: Tetrode is used as called amplifier.

Experiment 4: To verify-Child Langmuir law of space charge limited current using diode valve

Structure

4.1 Object:

After performing this experiment, you should be able to

- What are vacuum tubes specially diode
- Working of diode
- What is space charge limited region
- How current depends on potential in space charge limited region

4.2 Introduction:

Diode valve is a vacuum tube having two electrodes namely plate and cathode inside evacuated glass tube. It works on the principle of thermionic emission. For the proper use of the diode valve plate is kept at high potential with respect to cathode. When cathode of diode is heated by passing current in it, the cathode emits electrons. These electrons are collected by plate, which is at positive potential with respect to cathode. Electrons flow from cathode to plate, thus plate current flows in plate circuit. As plate voltage increases the plate current also increase. The current in circuit is controlled by plate and grid potentials. The plate current flows in the circuit only when plate is positive potential with respect to cathode and direction of flow of electron is always from cathode to plate never plate to cathode. Because of this unidirectional flow of current, diode is called 'diode valve'.

At constant temperature of cathode the variation of plate current with the plate voltage is non linear and plate current is controlled by space charge. The current is called space charge limited current.

4.3 Apparatus Used:

The diode valve, 6.3 volt heating filament (cathode), high tension source for plate (around 250V), voltmeter (0-250V) , milliammeter (0-10 mA) and Rheostat (100Ω), connection wires.

4.4 Theory and Formula Used:

Diode valve is two electrode namely plate and cathode. When cathode of the diode valve is heated, the electrons are emitted from the surface of cathode. The number of electrons emitted depends on temperature of the cathode. The first group of emitted electrons gathers in the space surrounding the cathode. It exerts repealing electrostatic force to next emitted charge, which therefore start to return to cathode. Their return is however prevented by next group of emitted electrons. Thus the dense cloud of electron is formed in space around cathode. This electron cloud is space charge. This space charge repeals the further emitted electron. When plate is given small positive potential, some of the electrons near the plate is attracted by plate and constitute current. If we further increase plate potential, the plate current also increases. This current only depends on space charge, plate potential and independent of temperature of cathode.

The variation of plate current to the plate voltage is non-linear and is given by Child-Langmuir law as

$$I_P = KV_p^{3/2} \qquad (1)$$

Where I_P is plate current

V_p is plate voltage, K is proportionality constant

Taking log on both side of equation (1)

$$\text{Log } I_P = 3/2 \text{ Log } V_p + \text{Log } K \qquad (2)$$

So as in equation (2) if we plot graph between Log V_p and Log I_P, it comes out straight line. If the slope of the straight line is 3/2, then it proves validity of Child-Langmuir law.

4.5 About apparatus:

The apparatus in the experiment is a simple electric circuit as shown in figure 1. The triode valve have three electrode 6V battery is connected to the electric bulb with rheostat. For the measurement of current and voltage the DC Voltmeter (0-10V) & DC ammeter (0-1 A) are connected.

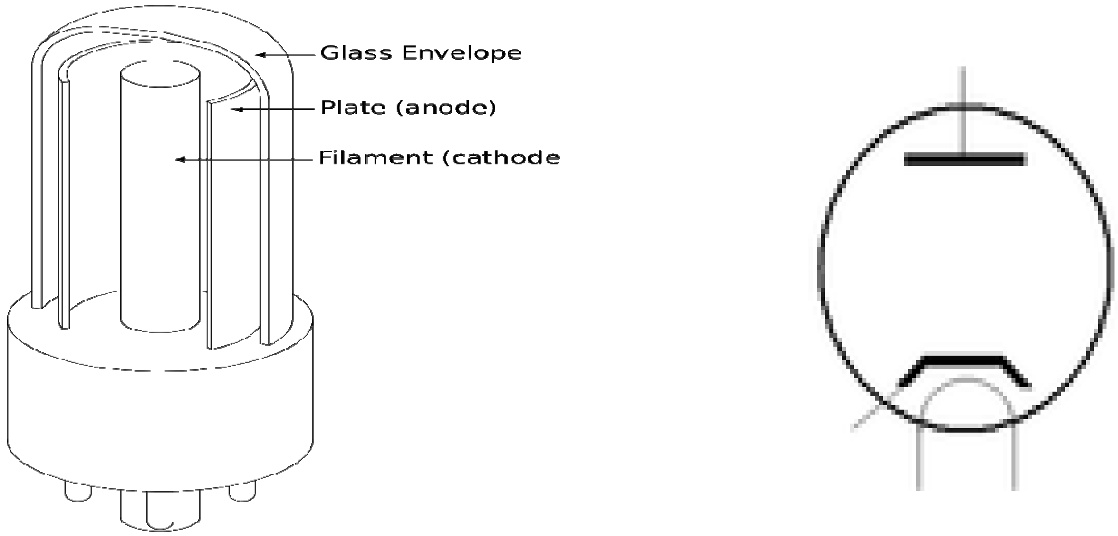


Figure 1

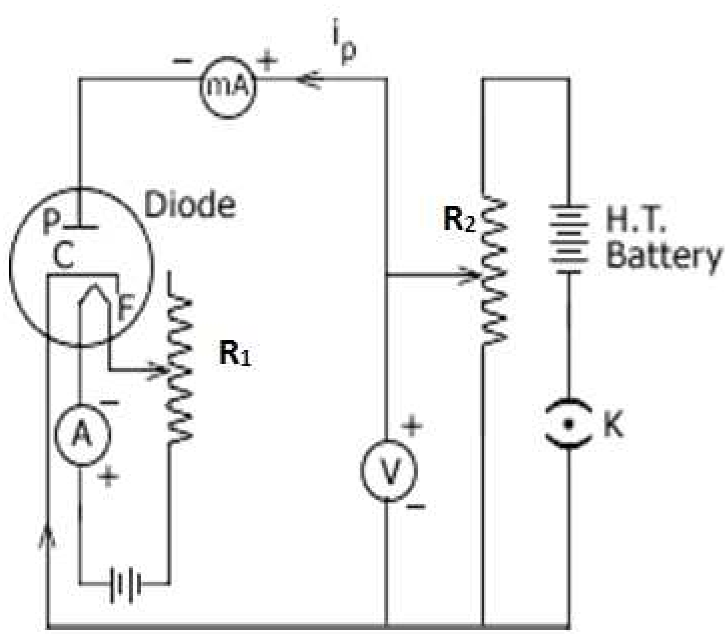


Figure 2

4.6 Procedure:

For plate characteristics, perform the experiment in following steps.

18. Make electrical connection as shown in figure 2.
19. With the help of rheostat (by varying resistance R_2) adjust to minimum plate voltage.

20. Note down the plate current in milliamter.
21. Now increase the plate potential in the steps (say in 2V step) and read the corresponding plate current in milliamter.
22. Draw the graph between plate voltage and plate current, which is called plate characteristics of diode.
23. Plot the graph between Log V_p and Log I_P, it comes out straight line..
24. Find the slope of graph plotted.

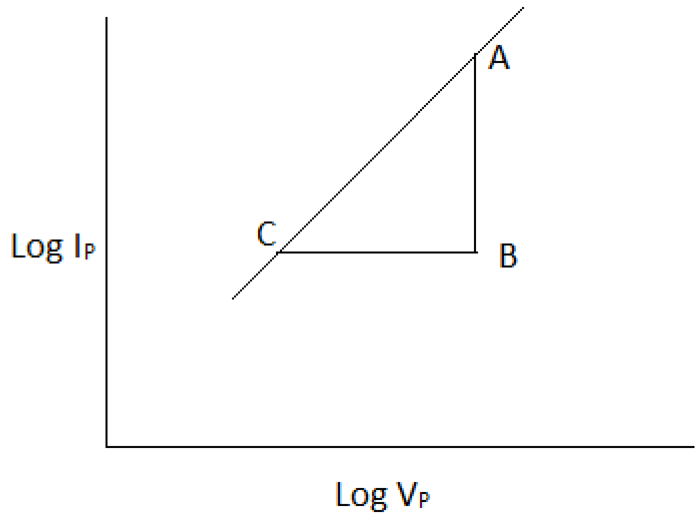
4.7 Observation:

Table1.For plate Voltage and plate current

1	Plate Voltage V_p Volt	Plate current I_P mA	Log V_p	Log I_P
2				
3				
4				
5				
6				
7				
8				
9				
10				

4.8 Calculation and Discussion:

The graph plotted between LogV_p and Log I_P is straight line and the slope of the straight line and slope of the straight line = $\frac{AB}{AC}$



4.9 Result:

The graph between LogV_p and Log I_P comes out straight line and the slope of the straight line is ………….., which prove validity of Child-Langmuir law.

4.10 Precaution and source of error:

18. Sensitive voltmeter and sensitive ammeter sould be used.
19. The direction about maximum plate voltage and filament voltage by manufacturer should be strictly followed.
20. Initiallty the plate voltage should be adjusted at minimum value.
21. There should not be any fluctuation on the power.
22. Reading are taken only for space charge limited region.
23. The graphs should drawn smothly.

4.11 Summary:

18. A vacuum diode is a device which works on the principle of thermionic emission.
19. Diode has two electrode namely plate cathode.
20. When plate potential increases, the plate current also increases.
21. Current is of order milliampares flows in circuit.
22. The graph between LogV_p and Log I_P is straight line in space charge limited region.

4.12 Glossary

` Vacuum Tube: It is evacuated glass tube in which electrodes are fitted.

Filament: It is a cathode, which emits electrons after heating.

Rheostat: It is used to vary potential

Rectifier: It the device which convert AC into DC.

Resistance: Obstruction to the flow of current.

4.13 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
3. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
4. B.L.Thereja *A Hand book of electronics* S. Chand publication, Delhi.
5. V.K.Mehta and Rohit Mehta,*Principle of electronics* S. Chand publication, Delhi.
6. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
7. *https://en.wikipedia.org.*

4.14 Viva-voce questions:

Question1. Define the process of thermionic emission?

Answer: When metal filament is heated, it emits electron from its surface. The phenomenon of emission of electrons by heating is called thermionic emission.

Question2. State Child-Langmuir law?

Answer: The space charge limited current in vacuum diode is proportional to 3/2 power of the plate voltage i.e. $I_P = KV_p^{3/2}$

Question3. Define space charge?

Answer. When cathode of diode valve is heated, the electron emitted from surface of cathode. These emitted electrons make cloud in spece between cathode and plate and they repeal the further emitted electron from cathode. This cloud of negatively charged is called space charge.

Question4. What is the use of diode valve?

Answer: Diode valve is used in rectification i.e. it covert AC signal to DC signal.

Experiment 5: To draw characteristics of PN junction diode

Structure

5.1 Object:

After performing this experiment, you should be able to

- What are semiconductor device
- Formation of PN junction diode
- Characteristics of PN junction diode.
- Use of PN junction diode.

5.2 Introduction:

Semiconductors are the material whose conductivity lies between conductor and insulator. Atoms of semiconductors are attached by covalent bonds. At absolute zero temperature semiconductor is insulator as no free electron to conduct and at higher temperatures semiconductor behave as conductor due free electrons which are produced by brakeage of some bonds. By Adding impurity of trivalent and pentavaleny impurity, the pure semiconductor is made P and N type semiconductor respectively. In P type semiconductor there are holes as majority charge carrier and electrons in minority and in N type semiconductor electrons are in majority and holes are in minority charge carrier.

A P-N junction is made by diffusing N type semiconductor with P type semiconductor.

5.3 Apparatus Used:

P-N junction diode, milliammeter and microammeter, Rheostat (100Ω), voltmeter, battery and connection wires.

5.4 Theory and Formula Used:

A PN junction diode is a semiconductor crystal having acceptor impurities (P type) in one region and donor impurities (N type) in another region. The boundary between two regions is called PN junction. The characteristics property of PN junction is that current can be pass through it much more easily in one direction than in other.

As shown in figure 1, the P region has holes (positive) as majority charge carriers and equal numbers of fixed negatively charge acceptor ions (The material as hole is neutral). Similarly, N type region has electrons (negative) as majority and equal number of fixed positively charged donor ions. In addition to majority charge carriers, there are few minority charge carrier in each region. The P region contains few electrons and N region contains few holes.

When the P region is diffused over N region, there forms a depletion region of order 10 μM and a junction (potential barrier of 0.1 to 0.5V) is formed. In the absence of any external voltage applied across the PN junction there is no current in diode. Under this condition few minority charge carriers have sufficient energy to cross over the junction. This constitutes equal and opposite current and hence balances and net current is zero. By applying external voltage, the junction is made conductive in following two ways

(III) **Forward Bias:** When +ve end of battery is connected to P region and -ve end of battery connected to N region of PN junction, A electric field is set up directed from P to N inside the semiconductor. When the external voltage exceeds the junction barrier potential, the holes move from P to N region and electrons move from N to P region. The moving majority charge carriers constitute current which increases on increasing external voltage and become saturated after some vale of external voltage. This biasing is called forward bias as shown in Figure 2.

(IV) **Reverse Bias:** When -ve end of battery is connected to P region and +ve end of battery connected to N region of PN junction, A electric field is set up directed from N to P inside the semiconductor. This biasing is called reverse bias as in Figure 3. In this condition the majority holes in P region and electrons in N region will not cross the junction, but few minority charge carrier will cross the barrier. The current constituted by minority charge carries will form small reverse current. When reverse voltage is increased, the fast moving minority electron will break the covalent bond, which will available the charge carrier. In this condition a large amount of reverse current will flow. This condition is called avalanche breakdown.

5.5 About apparatus:

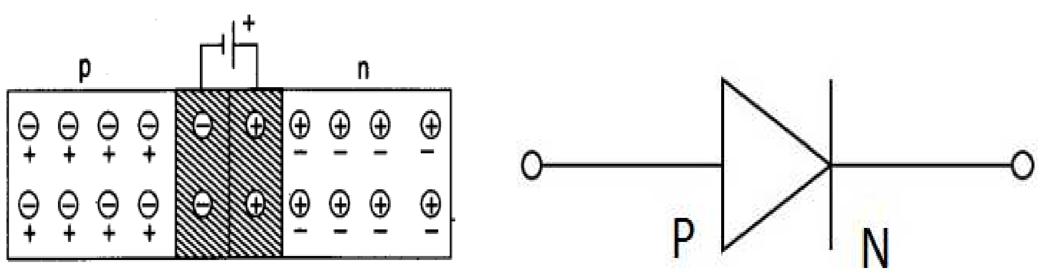


Figure 1

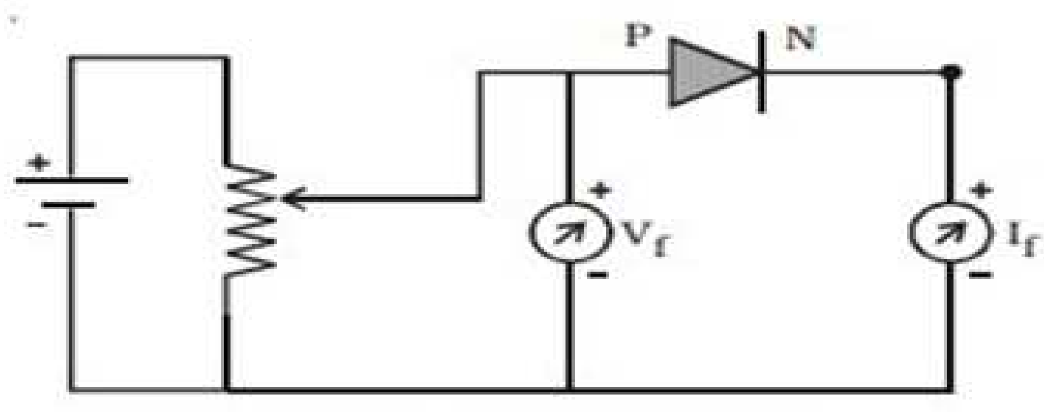


Figure 2 Forward bias

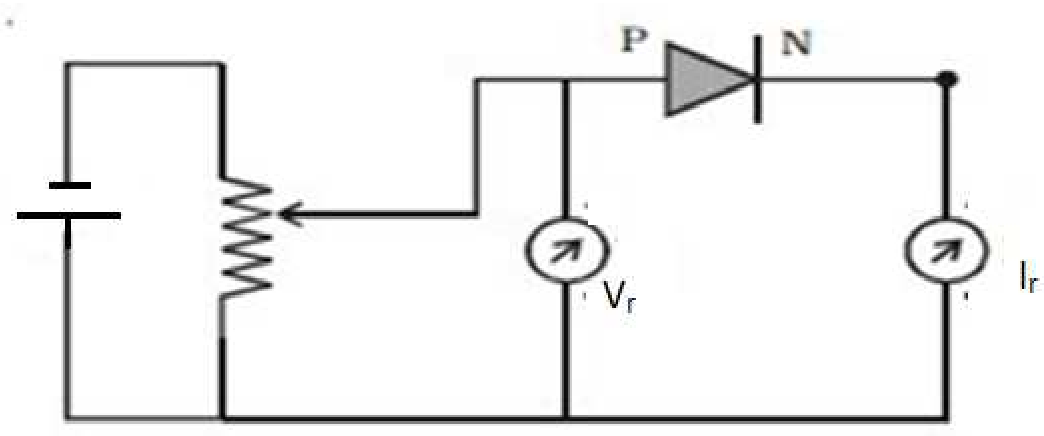


Figure 3 Reverse bias

5.6 Procedure:

For Forward bias

25. Make connection as shown in circuit diagram (figure 2).
26. With the help of rheostat vary the applied voltage in step of 0.1V.
27. Note down the ammeter reading in milliamter.
28. Draw the graph between voltage V_f and current I_f.

For Reverse bias

1. Make connection as shown in circuit diagram (figure 3).
2. With the help of rheostat vary the applied voltage in step of 0.5V.
3. Note down the ammeter reading in micrometer.
4. Draw the graph between voltage V_r and current I_r.

5.7 Observation:

Table1.For plate characteristics

S.N.	Forward bias		Reverse bias	
	Voltage V (In V)	Current I (In mA)	Voltage V (In V)	Current I (In mA)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

5.8 Result: The forward and reverse characteristics of PN junction diode is presented the graph.

5.9 Precaution and source of error:

24. Sensitive voltmeter and sensitive ammeter sould be used.

25. The direction about maximum plate voltage given by manufacturer should be strictly followed.
26. The graphs should drawn smothly.
27. There should not be any fluctuation on the power.
28. To avoid over heating of PN junction, current should not passed for long time.

5.10 Summary:

23. By addition of trivalent and pentavalent impurity pure Ge or Si become P and N type semiconductor respectively.
24. A junction is formed when N type semiconductor is diffuse over N type semiconductor. This is called PN junction.
25. The PN junction conduct when forward bias. So can be used as rectifier.
26. The current in PN junction is carried by electrons and holes.

5.11 Glossary

` Semiconductor: Materials that conduct to electricity between conductor and insulator.

Extrinsic semiconductor: Impure semiconductor for increasing conductivity.

Forward bias: When P is given +ve and N is given –ve voltage.

Reverse bias: When P is given -ve and N is given +ve voltage.

Rheostat: It is used to vary potential

Rectifier: The device which chanhes AC voltage to DC voltage.

Resistance: Obstruction to the flow of current.

5.12 References:

8. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
9. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
10. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
11. B.L.Thereja *A Hand book of electronics* S. Chand publication, Delhi.
12. V.K.Mehta and Rohit Mehta,*Principle of electronics* S. Chand publication, Delhi.
13. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
14. *https://en.wikipedia.org.*

5.13 Viva-voce questions:

Question1. What is meant by P type and N type semiconducor?

Answer: If we add III group impurity as boron (B), aluminum (Al) to pure semiconductor (Ge or Si), then the charge carriers are holes. This resultant material is called P type semiconductor.

On other 1.hand If we add V group impurity as arsenic (As), antimony (Sb) to pure semiconductor (Ge or Si), then the charge carriers are electrons. This resultant material is called N type semiconductor.

Question2. How PN junction is formed?

Answer: When the P type semiconductor is diffused over N type semiconductor the movement of hole (from P type semiconductor) and electrons (from N type semiconductor) leaves their parent atoms as ions. These ions restrict further movement of charge carriers hence form a junction called PN junction.

Question3. What will happen if high voltage is applied to PN junction?

Answer. In this case high current will flow and will damage the junction.

Question4.What is order of current in junction.

Answer: In forward bias, current is in milliampere while in reverse current is in microampere.

Experiment 6: To plot the characteristics of Zener diode and study of Zener diode as a voltage regulator

Structure

6.1 Object:

After performing this experiment, you should be able to

- What are semiconductor device
- Formation of Zener diode
- Characteristics of Zener diode
- Power regulation of Zener diode

6.2 Introduction:

Semiconductors are the material whose conductivity lies between conductor and insulator. Atoms of semiconductors are attached by covalent bonds. At absolute zero temperature semiconductor is insulator as no free electron to conduct and at higher temperatures semiconductor behave as conductor due free electrons which are produced by brakeage of some bonds. By Adding impurity of trivalent and pentavalent impurity, the pure semiconductor is made P and N type semiconductor respectively. In P type semiconductor there are holes as majority charge carrier and electrons in minority and in N type semiconductor electrons are in majority and holes are in minority charge carrier.

Zener diode is a heavily doped PN junction used in reverse bias. In Zener diode the current (reverse) remains constant over long voltage range until avalanche breakdown occurs. Due to this reason, Zener diode is used in voltage regulation

6.3 Apparatus Used:

Zener diode, microammeter, rheostat (100Ω), voltmeter, battery and connection wires.

6.4 Theory and Formula Used:

Zener diode is PN junction whose both P and N regions are heavily doped. Due to heavy doping depletion layer is narrow. When reverse voltage become more than Zener voltage and less than avalanche breakdown voltage, the current increases abruptly due to sudden increase of hole-electron pairs. The electron having energy less potential barrier has finite probability to penetrate barrier. It is quantum mechanical phenomena and potential barrier penetration of PN junction is explained by tunneling effect.

At Zener breakdown, large and saturated current flows in diode. It happens nearly at 20V and called Zener voltage. If the reverse voltage is increased further the current will not change because Zener voltage is sufficient to attract all the electrons produce at Zener breakdown. This property Zener diode can be used it in voltage regulator.

6.5 About apparatus:

The symbol of Zener diode is presented in figure1. The apparatus of Zener diode to study its characteristics is a circuit in which PN junction is revere biased and a resistance R_1 is connected to series with Zener diode. The input voltage is varied with the help of rheostat. The circuit diagram is presented in figure 2.

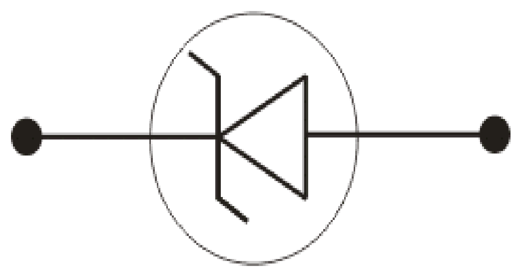


Figure 1

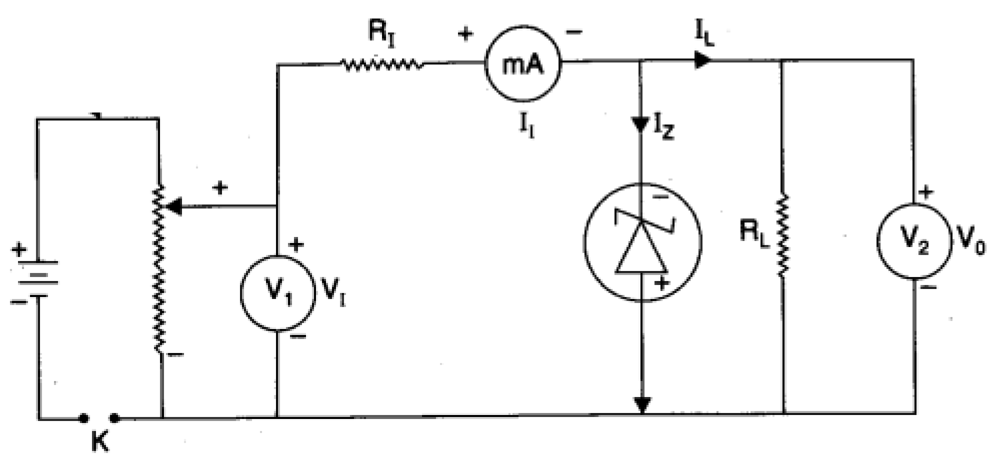


Figure 3 Reverse bias

6.6 Procedure:

For Zener characteristics

5. Make connection as shown in circuit diagram (figure 2).
6. With the help of rheostat vary the applied voltage in step of 1V.

7. Note down the ammeter reading in micrometer up to zener breakdown.
8. Draw the graph between voltage V and current I.

For Zener diode as voltage regulator (varying inputs)

1. Make connection as shown in circuit diagram (figure 2).
2. For a given input voltage, measure the output voltage across Zener diode.
3. Measure the output voltage across Zener diode on changing input voltage.
4. Draw the graph between output voltage V_O and input voltage V_I.

For Zener diode as voltage regulator (varying loads)

1. Make connection as shown in circuit diagram (figure 3).
2. For a given input voltage, measure the output voltage across Zener diode.
3. Measure the output voltage across Zener diode on changing load in output circuit R_L.
4. Draw the graph between load R_L and output voltage.

6.7 Observation:

Table1.For Zener characteristics

S.N.	Voltage V (In V)	Current I (In mA)
1		
2		
3		
4		
5		
6		
7		
8		
9		

10		

Table2. For Zener diode as voltage regulator (varying inputs)

S.N.	Input voltage V (In V)	Output voltage V (In V)
1		
2		
3		
4		
5		
6		

Table3. For Zener diode as voltage regulator (varying loads)

S.N.	Loads (In KΩ)	Output voltage V (In V)
1		
2		
3		
4		
5		
6		

6.8 Results:

1. The characteristics of Zener diode is presented the graph and Zener breakdown occurs at………………volts.
2. The output voltage across Zener is constant on varying input voltage for the input range ……….
3. The output voltage across Zener in constant on varying loads in output circuit for load range…………..

6.9 Precaution and source of error:

29. Sensitive voltmeter and sensitive ammeter sould be used.
30. The direction about maximum reverse voltage given by manufacturer should be strictly followed.
31. The graphs should drawn smothly.
32. There should not be any fluctuation on the power.
33. To avoid over heating of junction, current should not passed for long time.

6.10 Summary:

27. Zener diode is a heavily doped PN junction used in reverse bias.
28. Zener breakdown occurs before avalanche breakdown due to thin junction.
29. The voltage across Zener is constant on varying input voltage.
30. The voltage across Zener is constant on varying loads in output circuit.

6.11 Glossary

` Semiconductor: Materials that conduct to electricity between conductor and insulator.

Extrinsic semiconductor: Impure semiconductor for increasing conductivity.

Doping: Adding impurity on pure semiconductor.

Tunnel effect: It is quantum mechanical phenomena for penetration through potential barrier. The electron having energy less potential barrier has finite probability to penetrate the barrier.

Voltage regulation: The constant output for varying inputs or loads.

Loads: High resistance in output circuit.

6.12 References:

15. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
16. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
17. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
18. B.L.Thereja *A Hand book of electronics* S. Chand publication, Delhi.
19. V.K.Mehta and Rohit Mehta,*Principle of electronics* S. Chand publication, Delhi.
20. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
21. *https://en.wikipedia.org.*

6.13 Viva-voce questions:

Question1. What is meant Zener breakdown?

Answer: A little current flows in Zener diode on applying voltage. At a voltage that is less than avalanche breakdown voltage, the current increases abruptly. This is called Zener breakdown

Question2. Is there any difference between Zener diode and ordinary PN junction diode?

Answer: Yes, Zener diode is heavily doped to achieve sharp breakdown before avalanche breakdown.

Question3.What is voltage regulation?

Answer: Voltage regulation ability of instrument to maintain constant output for varying load or input.

Experiment 7: To draw output characteristics of NPN transistor in common emitter configuration

Structure

7.1 **Object**:

After performing this experiment, you should be able to

- What is NPN transistor?
- How output characteristics of NPN transistor is drawn.
- What is use of NPN transistor?

7.2 **Introduction:**

With the advance of semiconductor the NPN and PNP transistor are most important device, which are used in amplification. As we know that P and N type semiconductor are made by doping trivalent and pentavalent impurity in intrinsic semiconductor respectively. The NPN transistor is made by sandwiching P type semiconductor by two N type semiconductor on either side. The middle portion of NPN transistor is called base and either portion is called emitter and collector. The base of NPN transistor is thin and lightly doped, while emitter is highly doped and collector is lightly doped and have wider region. As requirements the NPN transistor can be use in common emitter, common base and common collector configuration. NPN and PNP transistors are called bipolar devices as both hole and electron are responsible for conduction inside transistor.

7.3 **Apparatus Used:** NPN transistor, battery, DC Voltmeter (0-10V), DC ammeter (0-50 mA) and rheostat (100Ω).

7.4 **Theory and Formula Used**:

Common emitter configuration is most used configuration in amplification as its amplification factor (β) is very high. The circuit diagram of NPN transistor is presented in figure. In circuit the base-emitter junction is kept forward bias while emitter-collector junction is kept reverse bias.

Two N regions have mobile electrons (negative) as majority and hole as minority, while in middle section p region have mobile holes (positive) in majority and electrons as minority. As shown in figure 2, the N-P junction (emitter base junction) is made small forward bias and P-N junction (base collector junction) is made reverse bias. Under the forward bias the electrons in emitter move toward base, while holes move toward base o emitter. Since base is thin, most of electrons pass on collector and few of them combine with hole constitute base current from base to emitter. Electrons reaching collector is attracted by positive voltage given to collector and thus constituting collector current. There are following two characteristics of NPN transistor in common emitter configuration.

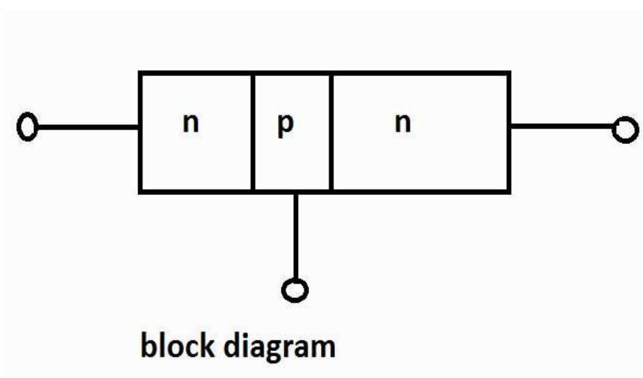
(a) Input characteristics: To draw the input characteristics, the collector voltage V_c is made zero. The emitter voltage V_e is increased from zero onward and corresponding emitter current I_e

is noted. Graph is plotted between emitter voltage V_e and emitter current I_e. Another graph is plotted for constant collector voltage V_c say for 25 volt. These curves show **input characteristics** of NPN transistor.

(b) Output characteristics: These characteristics are obtained by plotting collector current I_C versus collector-emitter voltage V_C at a fixed value of base current I_B. The base current is changed to some other fixed value and the observations of I_C versus V_{CE} are repeated .All the represents the output characteristics of a common-emitter circuit.

7.5 About apparatus:

The apparatus in the experiment is a NPN transistor as shown in figure 1. The base-emitter junction is forward bias by connecting 6V battery (i.e. P of junction is given +ve voltage and N is given –ve voltage) and bias while emitter-collector junction is kept reverse bias (i.e. P of junction is given -ve voltage and N is given +ve voltage). For the measurement of base current (input current) and collector current (output current) the microammeter and milliammeter are used in circuit.



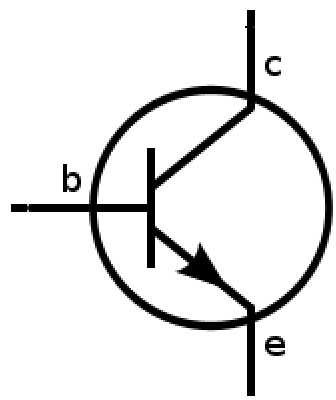


Figure 1

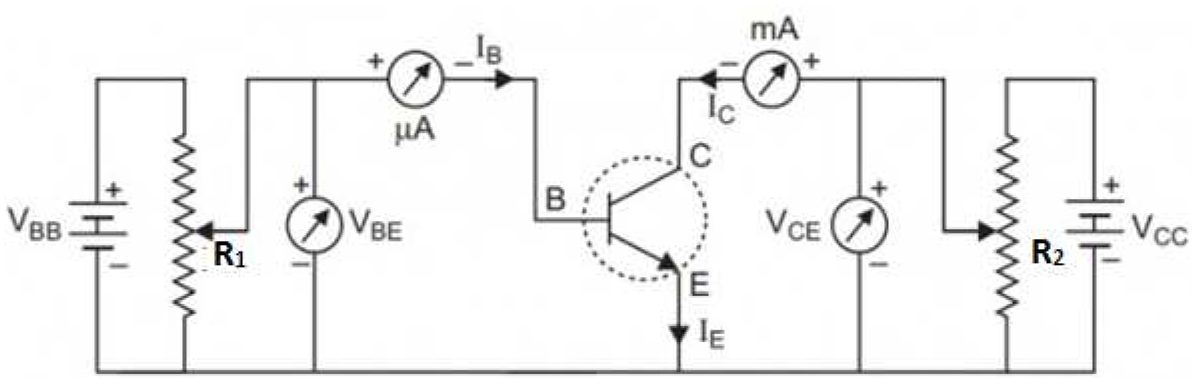


Figure 2

7.6 Procedure:

Let us perform the experiment in following steps.

29. Make connection as shown in figure 2.
30. Adjust base current say at 50 μA by means of R_1.
31. Increase collector voltage in step of 1 volt by changing R_2 and note the corresponding collector current.
32. Now note collector current with changing collector voltage for constant base current say for 75 μA, 100 μA, and 125 μA.
33. Plot curve between collector voltage and collector current at particular constant base current.

7.7 Observation:

Table for Output characteristics (I_C/V_C)

S.N.	Collector Voltage V_C (In volt)	Collector current I_C in mA for base current			
		I_b=50 μA	I_b=75 μA	I_b=100 μA	I_b=125 μA
1					
2					
3					
4					
5					
6					
7					
8					

7.8 Result: The output characteristics plotted between collector voltage V_C and collector I_C at constant base current I_b are plotted and presented in the graph .

7.9 Precaution and source of error:

34. Sensitive voltmeter and sensitive ammeter sould be used.
35. Specification about apparatus as given by manufacturer should be take care.
36. There should be proer biasing while performing experiment.
37. There should be not be fluctuation of power

7.10 Summary:

1.In Commen emitter transistor, the emitter section is used in both input circuit and output circuit.
2.Emitter-base junction is made forword bias.
3. Emitter-collector junction is made reverse bias.
4.The collector current increases on increase base current.
5. Base current of order 100µA and collector current mA flows in transistor

7.11 Glossary

Semiconductor: Material whose conductivity lies between conductor and insulator.

Intrinsic semiconductor: Si and Ge in their pure form.

Current amplification factor: It is the ratio of output current (collector current) and input current (base current).

Amplifier: A device which raises the strength of weak signal.

7.12 References:

22. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
23. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
24. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
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27. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
28. *https://en.wikipedia.org.*

7.13 Viva-voce questions:

Question1.What is a semiconductor transistor?

Answer: It is a semiconductor deice having three sections namely emitter, base and collector.

Question2. What is thickness of base section and what is region of it?

Answer: The thickness of base region is of order 10μ (10^{-5}M). It is made small so that minimum (2 to 3%) recombination of hole electron pair take place.

Question3.In how many ways a transistor can be used?

Answer. The transistor can be used in following three ways

(i) Common base configuration (CB)
(ii) Common emitter configuration(CE)
(iii) Common collector configuration(CC)

Question4. What is current gain in CE transistor?

Answer: It the ratio of collector current to base current. Its value is about 50.

Question5. Why CE configuration is preferred than CB configuration?

Answer: Due to its large current gain in CE than CB configuration

Question6. What is order of current in CE transistor?

Answer: The base current is order of 100μA, emitter & collector current is of order mA .

Experiment 8: To draw output characteristics of PNP transistor in common base configuration

Structure

8.1 Object:

After performing this experiment, you should be able to

- What is PNP transistor?
- How common base connection is made.
- How output characteristics of PNP transistor is drawn.
- What is use of PNP transistor?

8.2 Introduction:

With the advance of semiconductor the NPN and PNP transistor are most important device, which are used in amplification. As we know that P and N type semiconductor are made by doping trivalent and pentavalent impurity in intrinsic semiconductor respectively. The PNP transistor consists of a very thin slice N type semiconductor diffused by two by two type semiconductor on either side. The middle portion of PNP transistor is called base and either portion is called emitter and collector. The base of PNP transistor is thin and lightly doped, while emitter is highly doped and collector is lightly doped and have wider region. As requirements the NPN transistor can be use in common emitter, common base and common collector configuration. NPN and PNP transistors are called bipolar devices as both hole and electron are responsible for conduction inside transistor. The block diagram and symbols of PNP transistor is shown in figure1.

8.3 Apparatus Used:

PNP transistor, battery, DC Voltmeter (0-10V), DC ammeter (0-50 mA) and Rheostat (100Ω).

8.4 Theory and Formula Used:

The curves representing the variation of current with voltage in PNP transistor is called transistor characteristics. In Common base configuration the base is made common to both input and output. The circuit diagram of PNP transistor is presented in figure 2. In circuit the base-emitter junction (input circuit) is kept forward bias while base-collector (output circuit) junction is kept reverse bias. The voltage gain in this configuration is low and less than unity while voltage gain and power gain is high.

Two P regions have mobile holes (positive) as majority and electrons (negative) as minority, while in middle section N region have mobile electrons (negative) in majority and holes (positive) as minority. As shown in figure 2, the P-N junction (emitter base junction) is made small forward bias and N-P junction (base collector junction) is made reverse bias. Under the forward bias the holes in emitter move toward base, while electrons move toward base to emitter.

Since base is thin, most of holes pass on collector and few of them combine with electrons constitute base current from emitter to base. Holes reaching collector is attracted by negative voltage given to collector and thus constituting collector current. There are two characteristics of PNP transistor as following

(a) Input characteristics: To draw the input characteristics, the collector voltage V_c is made zero. The base voltage V_b is increased from zero onward and corresponding emitter current I_e is noted. Graph is plotted between base voltage V_b and emitter current I_e. Another graph is plotted for constant collector voltage V_c say for 25 volt. These curves show input characteristics of PNP transistor.

(b) Output characteristics: These characteristics are obtained by plotting collector current I_C versus collector voltage V_C at a fixed value of emitter current Ie. The base current is changed to some other fixed value and the observations of I_C versus V_{CB} are repeated represents the output characteristics of a common-emitter circuit.

8.5 About apparatus:

The apparatus in the experiment is a PNP transistor as shown in figure 1. The base-emitter junction is forward bias by connecting 6V battery (i.e. P of junction is given +ve voltage and N is given –ve voltage) and bias while base-collector junction is kept reverse bias (i.e. P of junction is given -ve voltage and N is given +ve voltage). For the measurement of base current (input current) and collector current (output current) the micro ammeter and milliammeter are used in circuit.

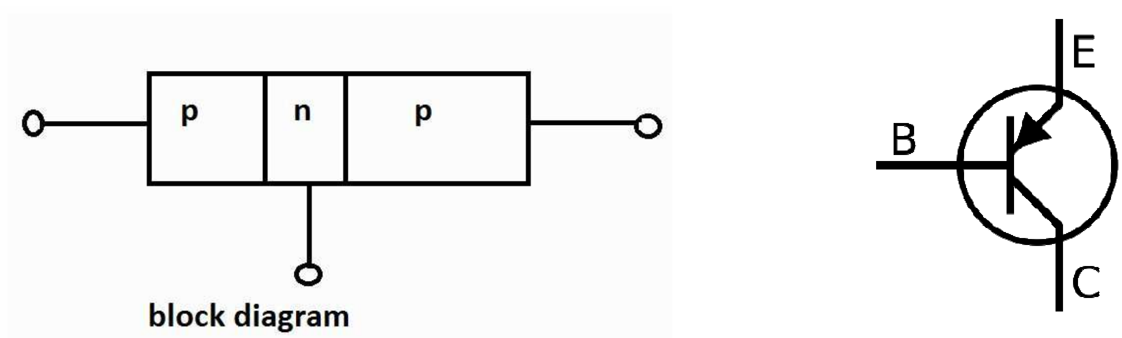

Figure 1

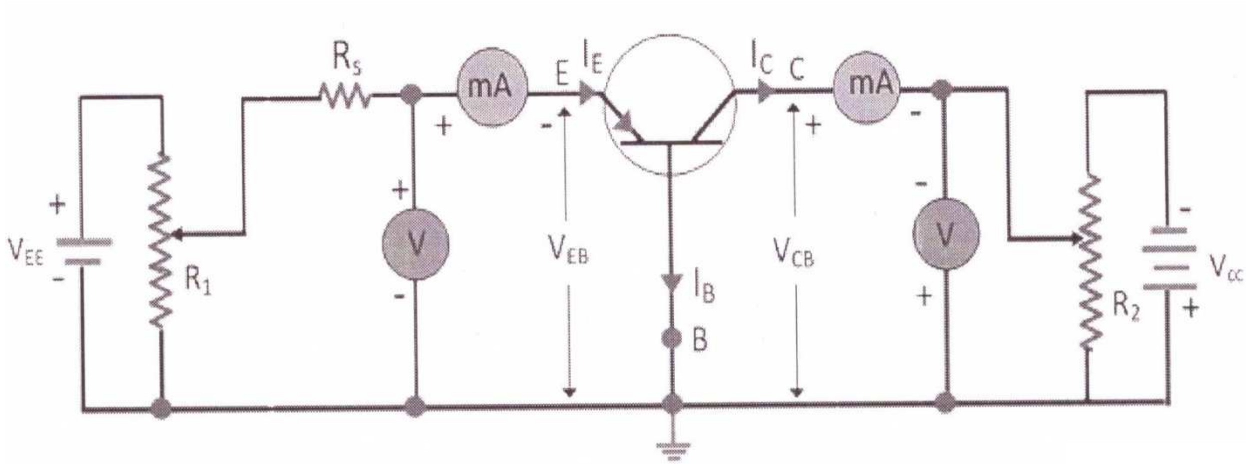

Figure 2

8.6 Procedure:

Let us perform the experiment in following steps.

34. Make connection as shown in figure 2.
35. Adjust emitter current say at 2 mA by means of R_1.
36. Increase collector voltage in step of 1 volt by changing R_2 and note the corresponding collector current.
37. Now note collector current with changing collector voltage for constant emitter current say for 4 mA, 6 mA, and 8 mA.
38. Plot curve between collector voltage and collector current at particular constant base current.

8.7 Observation:

Table for Output characteristics (I_C/V_C)

S.N.	Collector Voltage V_C (In volt)	Collector current I_C in mA for emitter current			
		I_e=2 mA	I_e=4 mA	I_e=6 mA	I_e=8 mA
1					
2					
3					
4					

5					
6					
7					
8					

8.8 Result:

The output characteristics plotted between collector voltage V_C and collector I_C at constant emitter current I_e are plotted and presented in the graph .

8.9 Precaution and source of error:

1. Sensitive voltmeter and sensitive ammeter sould be used.
2. Specification about apparatus as given by manufacturer should be take care.
3. There should be proer biasing while performing experiment.
4. There should be not be fluctuation of power

8.10 Summary:

1. .In Commen baser transistor, the base section is used in both input circuit and output circuit.

2.Emitter-base junction is made forword bias.

3. Base-collector junction is made reverse bias.

4.The collector current increases on increase emitter current.

5. Base current of order 100µA and emitter & collector current mA flows in transistor.

6. The current gain is low and less than unity in common base configuration.

7. The voltage gain and power gain is high in common base configuration.

8.11 Glossary

Semiconductor: Material whose conductivity lies between conductor and insulator.

Intrinsic semiconductor: Si and Ge in their pure form.

Current gainr: It is the ratio of output current (collector current) and input current (eitter current).

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8.12 References:

29. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
30. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
31. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
32. B.L.Thereja *A Hand book of electronics* S. Chand publication, Delhi.
33. V.K.Mehta and Rohit Mehta,*Principle of electronics* S. Chand publication, Delhi.
34. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
35. *https://en.wikipedia.org.*

8.13 Viva-voce questions:

Question1.What is a semiconductor transistor?

Answer: It is a semiconductor device having three sections namely emitter, base and collector.

Question2. What is thickness of base section and what is region of it?

Answer: The thickness of base region is of order 10μ (10^{-5}M). It is made small so that minimum (2 to 3%) recombination of holes and electrons take place.

Question3.In how many ways a transistor can be used?

Answer. The transistor can be used in following three ways

(iv) Common base configuration (CB)
(v) Common emitter configuration(CE)
(vi) Common collector configuration(CC)

Question4. What is current gain in CB transistor?

Answer: It the ratio of collector current to emitter current and is low (less than unity) in CB configuration.

Question4. What is relation of current gain in CB and CE configuration of transistor?

Answer: $\beta = \frac{\alpha}{1-\alpha}$, symbols are in usual meaning.

Experiment 9: To measure the hybrid parameters of PNP transistor in common emitter configuration

Structure

9.1 Object:

After performing this experiment, you should be able to

- What is common emitter configuration
- What are hybrid parameters
- What are unit of hybrid parameters

9.2 Introduction:

Every linear circuit having input and output terminals can be analyzed by four parameter (one measured in ohm, one in mho and two dimensionless) called hybrid parameter. Hybrid means mixed. Since these parameters have mixed dimensions so called hybrid parameters

Let consider a linear circuit shown in figure1 has input voltage (V_1) and current (I_1) and output voltage (V_2) and current (I_2)

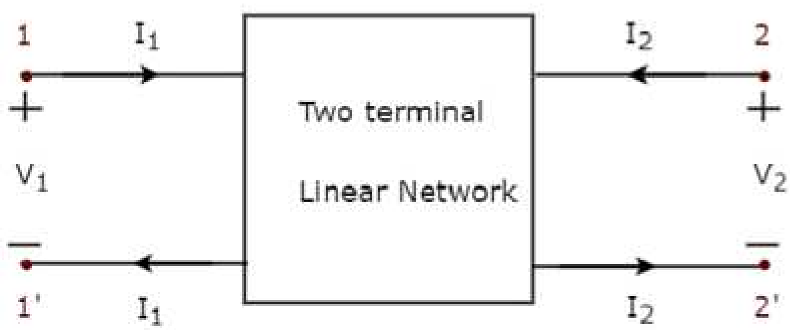

Figure1

Let $$V_1 = h_{11}I_1 + h_{12}V_2$$

$$I_2 = h_{21}I_1 + h_{22}V_2$$

In above equation h's are called hybrid parameter and it is fixed for given circuit. All the hybrid parameters can be determined by

(i) By putting $V_2 = 0$ (output circuit is short circuited)

$$h_{11} = \frac{V_1}{I_1}\text{, Input impedance}$$

$$h_{21} = \frac{I_2}{I_1}\text{, Forward current gain}$$

(ii) By putting $I_1 = 0$ (input circuit is open circuited)

$$h_{12} = \frac{V_1}{V_2}\text{, Reverse voltage gain}$$

$$h_{21} = \frac{I_2}{I_1}\text{, output admittance}$$

Two of above parameters h_{12} and h_{21} are dimensionless. Other two h_{11} and h_{22} have dimension of impedance and admittance.

9.3 Apparatus Used:

Transistor AC 126, two inductances, two resistances, capacitor, milliammeter (0-10mA), VTVM, AF oscillator, two batteries and connection wires.

9.4 Theory and Formula Used:

In case of transistor subscript b, e and c is written for common base, common emitter and common collector respectively. Hence the parameters h_{ie}, h_{re}, h_{fe} and h_{oe} stand for input impedance, reverse voltage ration, forward current gain and output admittance for common emitter configuration. Lets us design an amplifying circuit of PNP transistor in common base configuration as in figure 2.

When S in ON in above circuit and low signal (1K Hz) is applied between terminal 1 & 2 the current in input circuit I_b will be V_{31}/R_1 (As L_1 offered low impedance) and base-emitter voltage V_b isV_{23}. The current in output circuit will be $I_c = (V_{46}-V_{56})/R_2$

$$h_{ie} = \frac{V_b}{I_b} = R_1\frac{V_{23}}{V_{31}} \qquad\qquad h_{fe} = \frac{I_c}{I_b} = R_1\frac{V_{46}-V_{56}}{R_2V_{31}}$$

S in OFF in above circuit and low signal (1K Hz) is applied between terminal 5 & 6. So I_b will be zero, base-emitter voltage V_b is V'_{32} and $I_c = (V'_{56}- V'_{46})/R_2$

$$h_{re} = \frac{V_b}{V_c} = \frac{V'32}{V'46}, \qquad\qquad h_{oe} = \frac{I_c}{V_c} = \frac{V'56-V'46}{R_2V'46}$$

9.5 About apparatus:

The apparatus is a circuit of PNP transistor (AC 125) as shown in figure 2. The circuit have biasing voltage V_{BB} and V_{CC}, inductance L_1 and L_2 and capacitor C. 1 KHz signal will provided by AF oscillator. The voltage between ant two terminals will be measured by VTVM. The apparatus is amplifying PNP transistor in common emitter configuration.

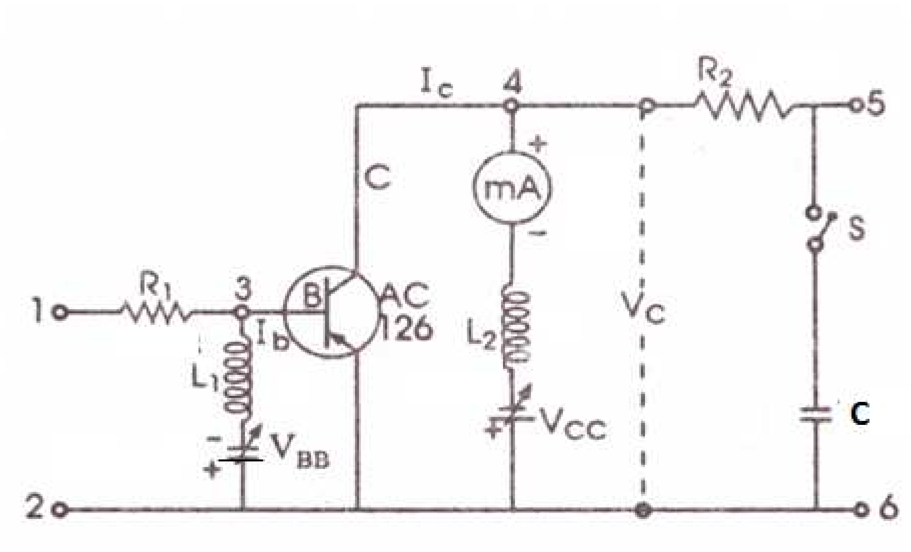

Figure 2

9.6 Procedure: let us perform following steps

1. For biasing of circuit there V_{BB} and V_{CC} adjusted such that I_C 2mA and V_{CE} is 5 volt.
2. Switch on (S) so $V_c = 0$
   Apply 1 KHz to input by AF oscillator (At 1and 2) set output voltage say 10 mV
   Measure V_{23}, V_{31}, V_{46} and V_{56}
3. Switch off (S) so $I_b = 0$
   Apply 1 KHz to input by AF oscillator (At 5and 6), set output voltage say 200mA or 300mA. And measure V'_{32}, V'_{46} and V'_{56}

9.7 Observation:

R_1 = ……………Ω R_2 = ……………Ω

S.N.	$V_c = 0$ (Switch S is ON)	$I_b = 0$ (Switch S is OFF)
1	V_{23} = ……………… volt	V'_{32} = ……………… volt
2	V_{31} = ……………… Volt	V'_{46} = ……………… volt

3	V_{46} =……………… volt	V'_{56} =……………… Volt
4	V_{56} =……………… Volt	

9.8 Calculation: The h parameters of transistor will be calculated by following observations

$$h_{ie} = R_1 \frac{V_{23}}{V_{31}}$$

$$h_{fe} = R_1 \frac{V_{46} - V_{56}}{R_2 V_{31}}$$

$$h_{re} = \frac{V' 32}{V' 46}$$

$$h_{oe} = \frac{V' 56 - V' 46}{R_2 V' 46}$$

9.9 Results: The h parameters for the given transistor at 1 KHz are

h_{ie} = ………… ohm
h_{re} = …………
h_{fe} = …………
h_{oe} = ………… ohm

9.10 Precaution and source of error:

38. Sensitive voltmeter and sensitive ammeter sould be used.
39. The direction about maximum reverse voltage given by manufacturer should be strictly followed.
40. The frequency should be adjusted carefully with oscillator.
41. There should not be any fluctuation on the power.
42. To avoid over heating of junction, current should not passed for long time.

9.11 Summary:

31. The ‘h’ parameters of circuit are mixed parameter as have mixed units.
32. Two parameters h_{re} and h_{fe} are dimensionless.
33. The ‘h’ parameters changes with temperature and operating point.

9.12 Glossary

` Semiconductor: Materials that conduct to electricity between conductor and insulator.

Common emitter configuration: Emitter of transistor is common to both input and output.

AF oscillator: Audio frequency generator of signal.

VTVM: Voltage tube voltmeter used to measure voltage (dC & AC), resistance etc.

9.13 References:

36. 1C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi.
37. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc III year)*, S. Chand publication, Delhi.
38. S.L.Gupta, V.Kumar *A Hand book of electronics* Pragati prakashan, Meerut.
39. B.L.Thereja *A Hand book of electronics* S. Chand publication, Delhi.
40. V.K.Mehta and Rohit Mehta,*Principle of electronics* S. Chand publication, Delhi.
41. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.
42. *https://en.wikipedia.org.*

9.14 Viva-voce questions:

Question1. What are hybrid ‘h’ parameters?

Answer: Mixed parameter since have mixed dimensions to describe the constant of four terminal (two input and two output) are called h parameters.

Question2. What is effect of temperature on ‘h’ parameters?

Answer: ‘h’ parameters change with temperature.

Question3. Is h’ parameters also changes with operating points of transistor?

Answer: yes.

Question4. For what value ‘h’ parameters of transistor can be found correct?

Answer: ‘‘h’ parameters can found correct for small signal.

Question5. What is dimension of h_{ie}?

Answer: Ohm.

Experiment 10: To plot output characteristics of FET and measure pinch off voltage

Structure

10.1Object:

After performing this experiment, you should be able to

- What is FET?

- What are bipolar and unipolar device.
- How the operation of FET is different from NPN and PNP transistor.
- What is use of FET?
- What is pinch off voltage?

10.2Introduction:

After the advance of semiconductor technology, because of small size, low operation voltage and low noise many semiconductor devices are manufactured and used. Among these all, FET have important and used in amplification. FET is a field effect transistor in which electric field controls the flow of current. As we know that P and N type semiconductor are made by doping trivalent and pentavalent impurity in intrinsic semiconductor respectively. FET is a three terminals device and is a semiconductor bar (either P or N type semiconductor) on which two PN junction is made on opposite sides in middle parts. The terminals from either side of bar along the bar are called drain and source terminals and terminal from PN junction is called gate. The FET is called unipolar device as current inside the bar is due to movements of only one type of charge carrier (i.e. holes or electrons). The symbolic diagram is presented in figure 1.

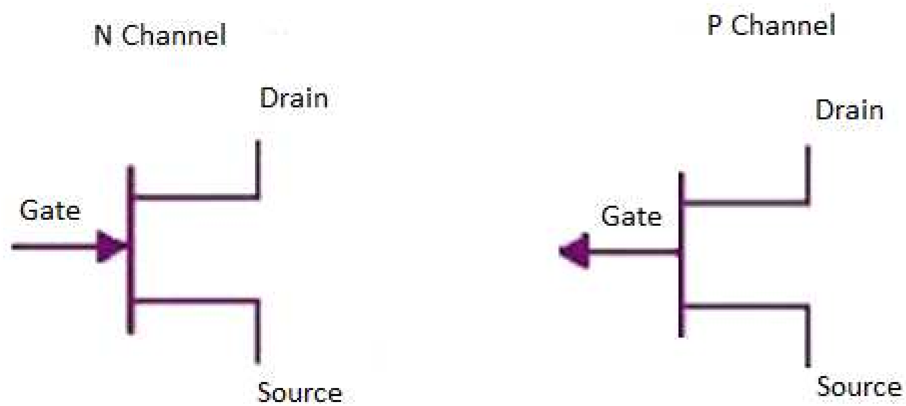

Figure 1

10.3Apparatus Used:

FET, DC power supplies for drain source and gate source biasing, DC Voltmeters (0-10V & 0-30V), DC ammeter (0-50 mA) and rheostat (100Ω).

10.4Theory :

The two PN junctions at the two sides of bar of conduction channel form depletion layers. The current through N channel bar is by electrons and in P channel bar is by holes. The width and hence resistance of channel can be controlled by changing the input voltage between gate and source V_{GS}. The greater reverse voltage V_{GS} will narrow the channel as the depletion layer of PN junction become wider.

The FET operate on the principle that the drain current through channel can be change by changing reverse gate source voltage V_{GS}. The working of FET is as

(1) When is drain kept at positive voltage (V_{DS}) with respect to source at zero gate potential, the drain current flows in channel of the FET. On increasing V_{DS} drain current increases and becomes saturated after a fixed voltage called pinch of voltage (V_P).
(2) When a reverse voltage V_{GS} is applied between gate and source, the depletion layers on the two sides of bar become wider and hence drain current decreases. The drain current I_p decreases on increasing reverse voltage V_{GS} and at some fixed reverse voltage the channel become completely cut off i.e. the drain current become zero. This reverse gate source voltage is called cut off voltage.

10.5About apparatus:

The apparatus in the experiment is a field effect transistor (FET) as shown in figure 2. The drain is kept at positive voltage with respect to source by the battery (0-30V) and gate is kept at negative voltage with the source by the battery (0-10V). For the measurement of drain current milliammeter is used in circuit.

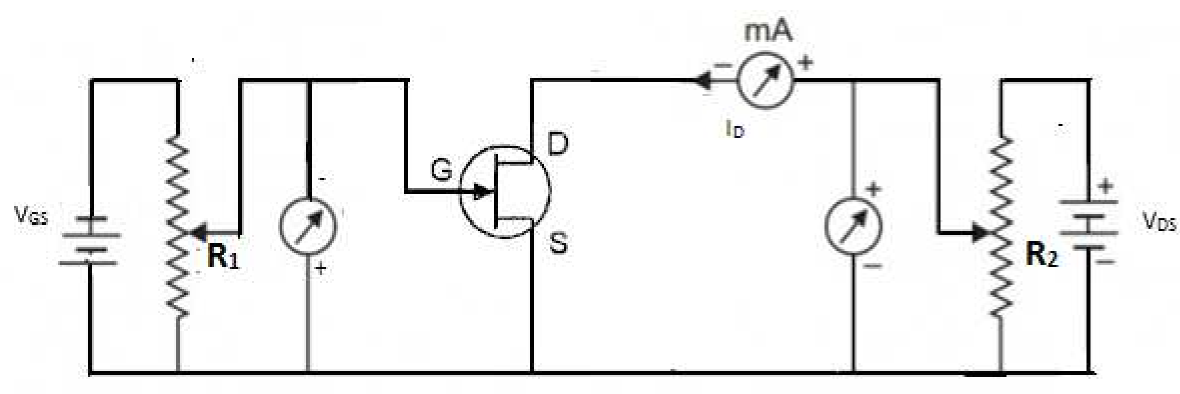

Figure 2

10.6Procedure:

Let us perform the experiment in following steps.

39. Make connection as shown in figure 2.
40. Adjust reverse gate voltage say at 1V by means of R_1.

41. Increase drain voltage in step of 1 volt by changing R_2 and note the corresponding drain current.
42. Now note drain current with changing drain voltage for constant reverse gate voltage say for 1V, 2V, 3V and 4Vetc.
43. Plot curve between drain voltage and drain current for constant reverse gate voltage.
44. Obtain the pinch off voltage from the graph between drain voltage and drain current.
45. Repeat the observation of drain current with drain voltage for different V_{GS} say1V, 2V, 3V and 4V and find the pinch off voltage.

10.7 Observation:

Table for Output characteristics (I_d/V_{DS})

S.N.	Drain Voltage V_{DS} (In volt)	Drain current I_d (mA) for base current			
		V_{GS}=1V	V_{GS}=2V	V_{GS}=3V	V_{GS}=4V
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

10.8Result:

The graph between drain voltage with drain current at constant gate source reverse voltage V_{GS} are plotted in the graphs and pinch off voltage V_P are ………....

10.9Precaution and source of error:

FET should handle carefully.

1. Sensitive voltmeter and sensitive ammeter sould be used.
2. There should be proper biasing i.e. gate is netaive and drain is positive with respect ro source.
3. Voltge should not exceeds the rated value of FET.
4. There should be not be fluctuation of power.

10.10 Summary:

1. FET is a three terminal unipolar device.

2. Three terminals in FET are called source, gate and drain.

3. Drain is always kept positive with respect to source, while gate is negative with respect to source.

4. Drain and source terminals are interchangeable.

5. The drain voltage for which drain current become saturate is called pinch off voltage.

10.11 Glossary:

Semiconductor: Material whose conductivity lies between conductor and insulator.

Intrinsic semiconductor: Si and Ge in their pure form.

Amplifier: A device which raises the strength of weak signal.

Unipolar device: The semiconductor inside which the conduction is by either (holes or electrons) charge carriers

Pinch off voltage: The drain voltage for the drain current becomes saturated is called pinch off voltage.

10.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

10.13 Viva-voce questions:

Question1.How a FET is different from npn/pnp transistor?

Answer: In FET current conduction is either by holes or electrons and is controlled by means by electric field while in npn/pnp transistor input current controls output current and conduction is due to both holes & electrons.

Question2. Define pinch off voltage?

Answer: It is drain-source voltage at which the drain current becomes constant.

Question3.What is use of FET?

Answer. FET is used as amplifier

Question4. What is biasing of gate in FET?

Answer: Reverse bias.

Experiment 11: To verify Thevenin's theorem

Structure

11.1 Objectives

11.1 Object:

After performing this experiment, you should be able to

- What is an electronic network?
- What is Thevenin's theorem?
- How the network is Thieveries?

11.2 Introduction:

Thevenin's theorem is an analytical method used to change a complex circuit into a simple equivalent circuit consisting of a single resistance in series with a source voltage. Thevenin's Theorem is especially useful in the circuit analysis of power or battery systems and other interconnected resistive circuits where it will have an effect on the adjoining part of the circuit.

Thevenin's Theorem states that "Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load". In other words, it is possible to simplify any electrical circuit, no matter how complex, to an equivalent two-terminal circuit with just a single constant voltage source in series with a resistance (or impedance) connected to a load as shown below.

As shown in figure 1 a linear circuit containing several voltage sources and resistance is replaced to a circuit having singe voltage source (voltage is called thevenin voltage) and single series resistance (thevenin resistance)

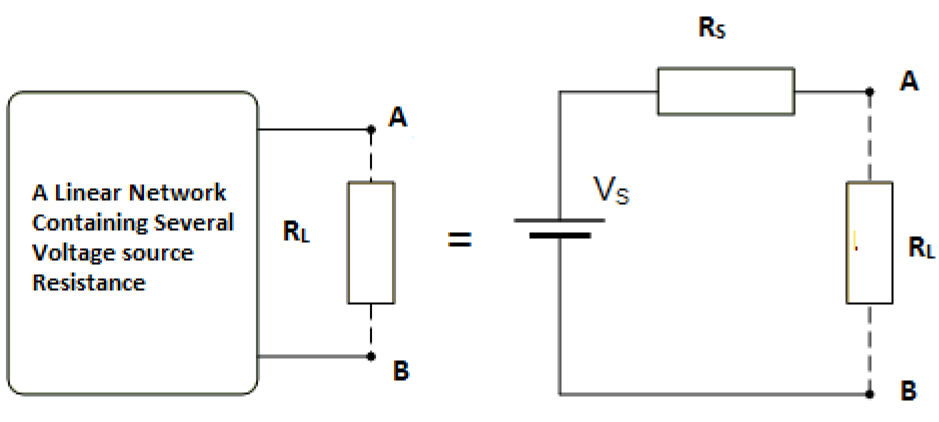

Figure 1

11.3 Apparatus Used:

DC voltage source (0-15V), voltmeter, milliammeter, resistances R_1=100Ω, R_2=330Ω, R_3=220 Ω , given network and different load resistance.

11.4 Theory and Formula Used:

Any two terminal linear circuit can be replaced by an equivalent circuit consisting of a source (having Thevenin's voltage) and series resistor.

Let take a dc circuit as shown in figure 2. We have to find out the current through load I_L. According to Thevenin's theorem dc circuit as shown in figure 2 can be replaced by its Thevenin's equivalent shown in figure 3.

(A) **Finding of thevenin's voltage V_{Th}** : It Is voltage between terminal of load when load is removed as shown in figure 4 and for the circuit 2 it will be

$$V_{Th} = V_{AB} = \frac{VR_3}{R_1 + R_3}$$

(B) **Finding of thevenin's resistance R_{Th}:** It is equivalent resistance between terminals of load looking in when load is removed and voltage terminals are short circuited as shown in figure 5 and for the circuit 2 it will be

$$R_{Th} = R_2 + \frac{R_1 R_3}{R_1 + R_3}$$

So, as Thevenin's theorem the current through load is given by

$$I_L = \frac{V_{Th}}{R_L + R_{Th}}$$

11.5 About apparatus:

The apparatus is a circuit having three resistances R_1, R_2 and R_3 and a voltage source V. For the measurement of load current ammeter is used. Current is measured for different load resistances.

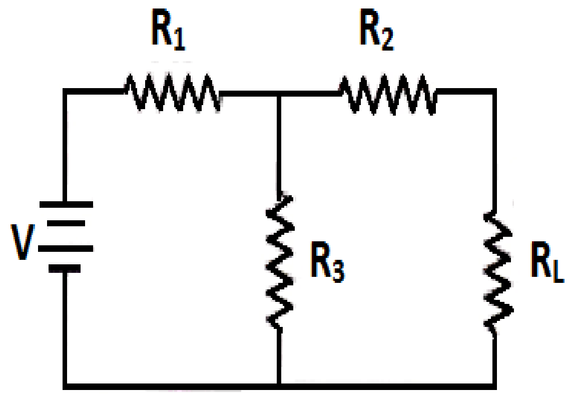

Figure 2

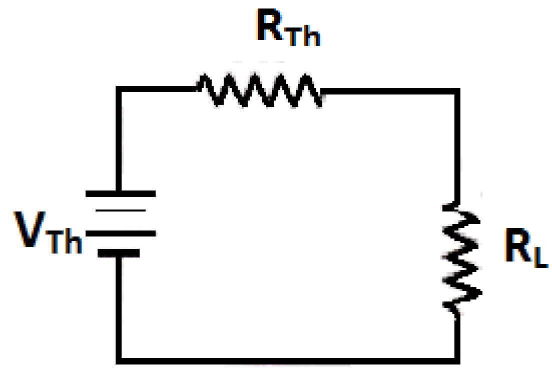

Figure 3

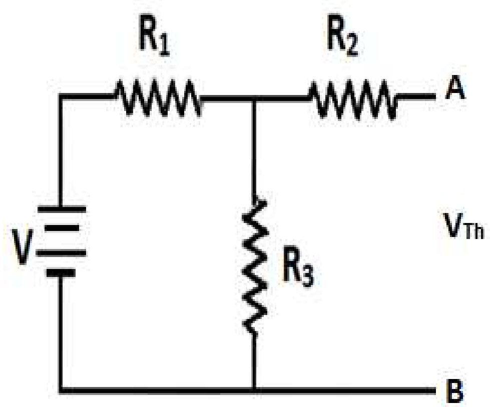

Figure 4

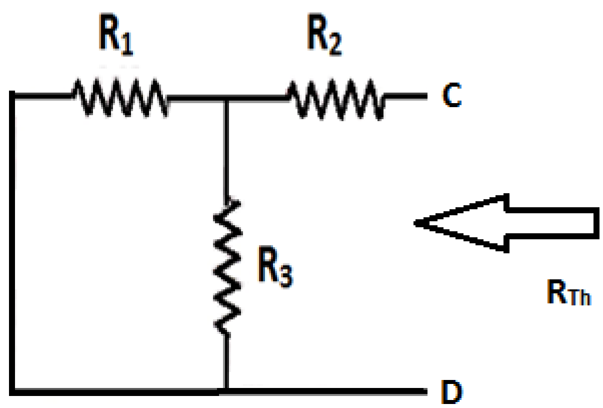

Figure 5

11.6 Procedure:

12 Make a circuit as figure 2 with load 100 Ω.
13 Set source voltage to 10 V.
14 Calculate thevenin's voltage V_{Th} and thevenin's resistance R_{Th}.
15 Calculate load current I_L.
16 With the help of milliammeter measure the load current I_L experimently.
17 Compare the calculated and experimently meassured load current I_L.

18 Perform the step 1-5 for the different load resistance say 200Ω, 300Ω, 400Ω and 500Ω.

11.7Theoretical calculation of load current I_L:

SN	Load resistance R_L	thevenin's voltage $V_{Th} = V_{AB} = \frac{VR_3}{R_1 + R_3}$	thevenin's resistance $R_{Th} = R_2 + \frac{R_1 R_3}{R_1 + R_3}$	I_L(mA)Current through load resistance I_L $I_L = \frac{V_{Th}}{R_L + R_{Th}}$
1	100Ω			
2	200Ω			
3	300Ω			
4	400Ω			
5	500Ω			

11.8Observation:

Table for measurement of the load current I_L

SN	Load resistance R_L	I_L(mA)Current through load resistance I_L
1	100Ω	
2	200Ω	
3	300Ω	
4	400Ω	
5	500Ω	

11.9Results: The theoretical calculations and experimental results are same for all loads, hence Thevenin's theorem is verified.

11.10 Precaution and source of error:

43. Sensitive voltmeter and sensitive ammeter sould be used.
44. Theoretical calculations and experimental results should be taken carefully.
45. There should no voltage flactuation of source.

11.11 Summary:

34. Electronic networks consist of voltage source, active and passive components.
35. Thevenin's theorem is one of the best ways to calculate current in any branch of the circuit.
36. A complex circuit can be replaced to a simple circuit by thevenin's theorem.

11.12 Glossary

` Electronic networks: Circuit having many voltage source and impedances.

Thevenin's voltage: Thevenin voltage is obtained by opening the specified terminals so it is open circuit voltage.

Thevenin's resistance: Equivalent resistance of the circuit between terminals of load looking in when load is removed and voltage terminals are short circuited.

11.13 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

11.14 Viva-voce questions:

Question1. State and explain Thevenin's theorem?

Answer: Any active linear bilateral network can be replaced by a single voltage source in series with resistance. The value of the voltage source is equal to the voltage across the open circuited load terminals and the value of resistance is equal to the resistance looking through the open circuited load terminals when ideal voltage sources are short circuited.

Question2. Limitations of Thevenin's theorem?

Answer: (a) Thevenin's theorem is applicable to only linear circuits

Experiment 12: To verify maximum power transfer theorem.

Structure

12.1Object:

After performing this experiment, you should be able to

- What is maximum power transfer theorem?
- The power transfer from source varies with load?

12.2Introduction:

In any electric circuit, the electrical energy from the supply is delivered to the load for converting a useful work. Practically, the entire supplied power will not present at load due to the heating effect of internal resistance in power supply and other constraints in the network. Therefore, there exist a certain difference between drawing and delivering powers.

The load always affects the amount of power transferred from the supply source to load, so any change in the load resistance will change in power transfer to the load. The maximum power transfer theorem ensures the condition to transfer the maximum power to the load. It state that maximum power is transferred from source to a load when load resistance is made equal to the internal resistance of the source.

12.3Apparatus Used:

DC circuit training system having DC Power supply and different load, voltmeter (V), milliammeter (mA) and Set of wires.

12.4Theory and Formula Used:

When load is connected across a voltage source, power is transferred from source to load. According to maximum power transfer theorem maximum power is transferred from source to a load when load resistance is made equal to the internal resistance of the source.

The maximum power transfer theorem is used to find the value of the load resistance for which the maximum power is transferred to the load.

As in figure 1, two terminal DC circuit in which the condition for maximum power is to determine. Any change in the load resistance will change in power transfer to the load.

In above circuit, the current in load (I_L) can be determined by kirchoff's law and is given by

$$I_L = \frac{V}{R_i + R_L}$$

Hence power delivered to load will be

$$P = I_L^2 R_L = \left(\frac{V}{R_i + R_L} \right)^2 R_L$$, where R_i is internal resistance of supply

Form the above expression the power delivered depends on the values of R_i and R_L. The power delivered from the source to the load entirely depends on the load resistance R_L. To find the exact value of R $_L$ for which maximum power is delivered can be found by differentiating to P with respect to R_L and equating it to zero as

$$\frac{dP}{dR_L} = V^2 \left[\frac{(R_i + R_L)^2 - 2R_L(R_i + R_L)}{(R_i + R_L)^4} \right] = 0$$

So, $$(R_L + R_i) - 2R_L = 0$$

$$\Rightarrow R_L = R_i$$

So, the maximum power transfer occurs when the load resistance is equal to the internal resistance of the circuit. By substituting the $R_i = R_L$.

12.5About apparatus:

The apparatus is a simple circuit as shown in figure 1 consists of power supply source having different loads. Loads ranges from 100ohm to 1000 ohms. Observation of current and voltage are taken for all the loads to found out power deliver to load.

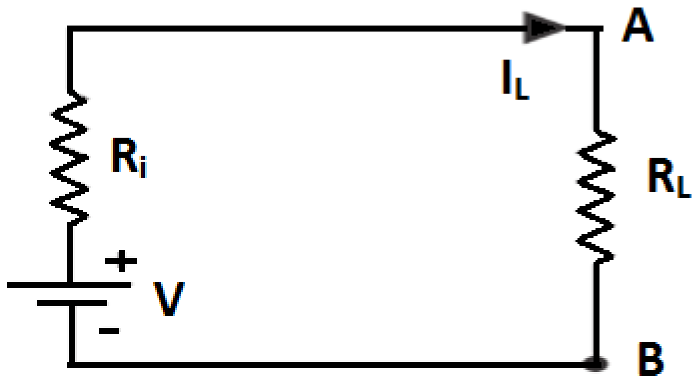

Figure 1

12.6Procedure:

1. Switch on the circuit as shown in figure1.
2. Keep R_L=100 ohm, note the current and voltage across the load.
3. Calculate, power P=VI for the load.
4. Repeat the process 1-3 for different loads.
5. Plot the graph between load and power deliver to load.
6. Mark the maximum power in the graph and calculate the load correspond the maximum power.
7. Compare the obtained load corresponds to maximum power and match the result to internal resistance of the power supply.

12.7Observation:

Table1. Table for the load resistance and output power

S.N.	Load R_L (In)	Current I (In mA)	Voltage (In V)	Power P=VI (In watts)
1				
2				
3				
4				

5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				

12.8Results:

The graph plotted between power and load is presented in graph and it is observed that power delivered to load varies with load and it is maximum to the load…………, which is equal to internal resistance of the source.

12.9Precaution and source of error:

46. Input voltage V_i, should be kept fixed.
47. Load of proper wattage should have be used.
48. There should be no flactuation of power in circuit.
49. Voltage and currents reading should taken carefully.
50. Graph should drawn smoothly.

12.10 Summary:

1. Power delivered to the load is the product of current and voltage across the load.

2. The power delivered to load by the power supply changes with the load and for the particular value of load resistance it become maximum. It is found that power delivered to load is maximum when load is equal to the internal resistance of the power supply.

12.11 Glossary

` Power: Power delivered to the load is the product of current and voltage across the load.

Internal resistance: It is the obstruction to the current from supply itself. Due to this the voltage across battery is always less than emf of battery.

Load: An electrical load is an electrical component or portion of a circuit that consumes (active) electric power.

12.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

12.13 Viva-voce questions:

Question1. State maximum power transfer theorem?

Answer: A load resistance connected to dc network receives maximum power when load is equal to internal resistance of the network.

Question2. What is efficiency during maximum power transfer?

Answer: 50%.

Question3. State maximum power transfer theorem for the AC network?

Answer: Maximum power will transfer to load from source when the load impedance is made equal to the complex conjugate of internal resistance of the source.

Question4. A source $V = V_0 Cos\pi t$ has internal impedance (4+3j), find the condition for the maximum power transfer?

Answer: The maximum power will transfer for the load of impedance (4-3j).

Experiment 13: To study of RC coupled amplifier

Structure

13.1Object:

After performing this experiment, you should be able to

- What is an amplifier?
- How coupling is done and its benefit?
- What is RC coupled amplifier?
- What is frequency response curve of RC coupled amplifier?

13.2Introduction:

The process of increasing the signal strength is called as amplification. The output from single stage amplifier is small and hence gain of single amplifier is inadequate for practical purposes. For this the output of one stage amplifier is coupled to input of next stage. This coupling is done by many ways and coupling through R & C is one best way of coupling. A practical amplifier is always multistage amplifier and used in transistor radio receiver.

In RC coupling amplifier the capacitor connect the output of one stage to the input of input of next stage. A capacitor blocks the dc hence it provide dc isolation between two stages of multistage amplifier.

13.3Apparatus Used:

Power supply, Measuring device (VTVM or CRO), transistor (BC107), AF signal generator, Resistances & Capacitors for biasing, stabilization.

13.4Theory and Formula Used:

When input AC. signal is applied to the base of the transistor of the 1st stage of RC coupled amplifier with the help of function generator, it is then amplified across the output of the 1st stage. This amplified voltage is applied to the base of next stage of the amplifier, through the coupling capacitor Cc where it is further amplified and reappears across the output of the second stage.

Resistance-capacitance (RC) coupling in amplifiers are most widely used to connect the output of first stage to the input (base) of the second stage and so on. This type of coupling is most popular because it is cheap and provides a constant amplification over a wide range of frequencies.

The RC coupled amplifiers in which the resistors R_1 and R_2 form the biasing network while the emitter resistor R_E form the stabilization network. Here the C_E is also called bypass capacitor which passes only AC while restricting DC, which causes only DC voltage to drop across R_E while the entire AC voltage will be coupled to the next stage.

The voltage gain of single stage amplifier is the ratio output voltage to input voltage.

$$Gain = \frac{V_{out\,put}}{V_{input}}$$

The frequency response of a RC coupled amplifier can be divided in to three regions

At low frequencies, the reactance of coupling capacitor C_C is high which causes a small part of the signal to couple from one stage to the other.

Over a wide range of mid-frequencies, the gain of the amplifier is constant.

At high frequencies, the reactance of C_C will be low which causes it to behave like a short circuit. This results in an increase in the loading effect of the next stage and thus reduces the voltage gain.

13.5About apparatus:

The apparatus is a circuit as presented in figure 1. It is a single stage common emitter npn transistor in which R_1 & R_2 provide biasing to the transistor through voltage $V_{cc,}$ R_4 & C_2 are used for the stability. C_2 provides coupling capacitor for the next stage. Input and output voltage is measured by VTVM/CRO.

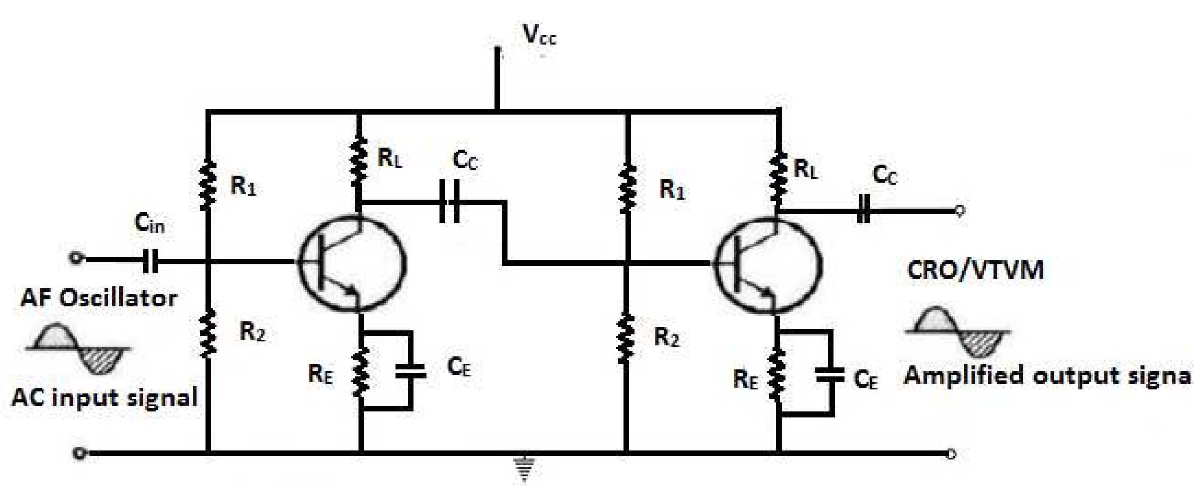

Figure 1: Two stages common emitter RC coupled amplifier

13.6Procedure:

1. Switch on the power supply.
2. With the help of VTVM/CRO, set the input voltage to V_{in}=10mV
3. On changing frequency of input note down the out voltage V_{out} by VTVM/CRO.
4. Calculate voltage gain.
5. Find voltage gain in decibel (db).
6. Plot graph between frequency and voltage gain (db).
7. Find the band width.
8. Repeat the observation for input voltage to V_{in}=20mV.

13.7Observation:

Table for measurement of output voltage for different input frequency

	Input voltage V_i=10mV			Input voltage V_i=20mV		
	Frequency	Output voltage (V_{out})	Gain=V_o/V_i	Frequency	Output voltage (V_{out})	Gain=V_o/V_i
S. N.						
1						
2						
3						
4						
5						
6						
7						
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9						
10						
11						
12						
13						
14						
15						

13.8Results: Frequency response of RC coupled amplifier is plotted.

Gain = …………. dB.

Bandwidth = ………….Hz.

13.9Precaution and source of error:

1. Resistances and capacitance in the circuit should be chosen carefully.
2. Sensitive measuring device VTVM/CRO should be used.
3. Frequency of input signal should be of wide range.
4. There should not fluctuation of power.

13.10 Summary:

3. The frequency response curve of RC coupled amplifier is constant over wide range of frequency while decreases at lower and higher frequencies.
4. Frequency response of RC amplifier has wide band width.
5. RC coupled amplifier is better as it is chief and have wider band width.

13.11 Glossary

RC coupled amplifier: It is device which raises the power of weak signal usualy used in audio amplifier.

Half-power points: These are the points where power becomes half to maximum power.

Band width: It is difference of frequencies of half-power points.

13.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

13.13 Viva-voce questions:

Question1. What is voltage gain?

Answer: It is the ratio of the output voltage to the input voltage.

Question2. Does the voltage gain depend on frequency?

Answer: Yes, at low and high frequency it is low and in mid frequency it is constant.

Question3. Why RC coupling is preferred in audio range?

Answer: This type of coupling is most popular because it is cheap and provides a constant amplification over a wide range of frequencies.

Question4. What is 3dB bandwidth?

Answer: 3 dB band width is difference of frequencies of half-power point.

Question5. Why the voltage gain reduces at high and low frequency?

Answer: At low frequency range, the reactance offered by coupling capacitor C_c ($1/\mu C$) increases as frequency decreases. At high frequencies, the reactance of coupling C_c will negligible hence having shunting effect.

Experiment 14: To study of TC coupled amplifier.

Structure

14.1 Object:

After performing this experiment, you should be able to

- What is an amplifier?
- How coupling is done and its benefit?
- What is TC coupled amplifier?
- What is frequency response curve of TC coupled amplifier?

14.2Introduction:

An electronic signal contains some information which cannot be utilized if doesn't have proper strength. The process of increasing the signal strength is called as amplification**.** Amplification in practical applications is done using Multi-stage amplifiers. A number of single-stage amplifiers are cascaded to form a Multi-stage amplifier

The output from single stage amplifier is small and hence gain of single amplifier is inadequate for practical purposes. For this the output of one stage amplifier is coupled to input of next stage. The main drawback of RC coupled amplifier is that the effective load resistance gets reduced. This is because, the input impedance of an amplifier is low, while its output impedance is high.

When they are coupled to make a multistage amplifier, the high output impedance of one stage comes in parallel with the low input impedance of next stage. Hence, effective load resistance is decreased. This problem can be overcome by a transformer coupled amplifier.

In a transformer-coupled amplifier, the stages of amplifier are coupled using a transformer.

14.3Apparatus Used:

Power supply, Measuring device (VTVM or CRO), transistor (BC107), AF signal generator, Resistances, Capacitors for biasing & stabilization and transformer for coupling.

14.4Theory and Formula Used:

When an AC signal is applied to the input of the base of the first transistor then it gets amplified by the transistor and appears at the collector to which the primary of the transformer is connected.

The transformer which is used as a coupling device in this circuit has the property of impedance changing, which means the low resistance of a stage (or load) can be reflected as a high load resistance to the previous stage. Hence the voltage at the primary is transferred according to the turns ratio of the secondary winding of the transformer.

This transformer coupling provides good impedance matching between the stages of amplifier. The transformer coupled amplifier is generally used for power amplification.

14.5About apparatus:

The amplifier circuit (figure 1) in which, the previous stage is connected to the next stage using a coupling transformer, is called as Transformer coupled amplifier.

The coupling transformer T_1 is used to feed the output of 1^{st} stage to the input of 2^{nd} stage. The collector load is replaced by the primary winding of the transformer. The secondary winding is connected between the potential divider and the base of 2^{nd} stage, which provides the input to the 2^{nd} stage. Instead of coupling capacitor like in RC coupled amplifier, a transformer is used for coupling any two stages, in the transformer coupled amplifier circuit.

The figure below shows the circuit diagram of transformer coupled amplifier.

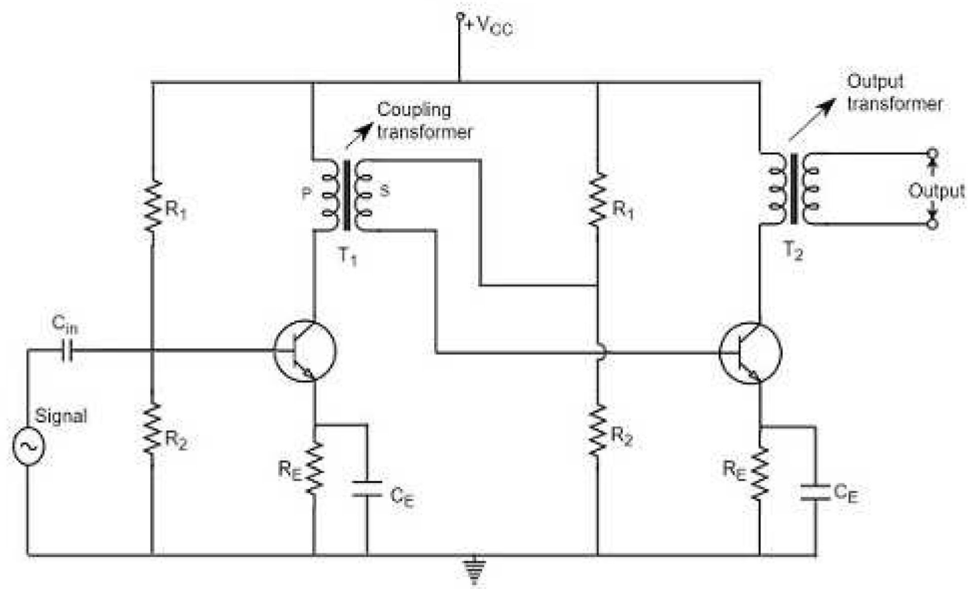

Figure 1

The potential divider network R_1 and R_2 and the resistor R_e together form the biasing and stabilization network. The emitter by-pass capacitor C_e offers a low reactance path to the signal. The resistor R_L is used as a load impedance. The input capacitor C_{in} present at the initial stage of the amplifier couples AC signal to the base of the transistor. The capacitor C_C is the coupling capacitor that connects two stages and prevents DC interference between the stages and controls the shift of operating point.

14.6Procedure:

9. Switch on the power supply.
10. With the help of VTVM/CRO, set the input voltage to V_{in}=10mV

11. On changing frequency of input note down the out voltage V_{out} by VTVM/CRO.
12. Calculate voltage gain.
13. Find voltage gain in decibel (db).
14. Plot graph between frequency and voltage gain (db).
15. Find the band width.
16. Repeat the observation for input voltage to V_{in}=20mV.

14.7Observation:

Table for measurement of output voltage for different input frequency

	Input voltage V_i=10mV			Input voltage V_i=20mV		
	Frequency	Output voltage (V_{out})	Gain=V_o/V_i	Frequency	Output voltage (V_{out})	Gain=V_o/V_i
S. N.						
1						
2						
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13						
14						
15						

14.8Results: Frequency response of TC coupled amplifier is plotted.

Gain = …………. dB.

Bandwidth = ………….Hz.

14.9Precaution and source of error:

5. There should not any fluctuation of power.
6. Transformer terminals should not meet.
7. Sensitive measuring device VTVM/CRO should be used.
8. Frequency of input signal should be of wide range.

14.10 Summary:

6. Amplifier is a device one who raises the strength of weak signal
7. TC coupled amplifier are used in impedance matching between two stages.
8. TC coupled amplifier are used as power amplifier.
9. Band width is less than RC coupled amplifier.
10. At resonance there comes a kinks in frequency response of TC coupled amplifier.

14.11 Glossary

Aamplifier: It is device which raises the power of weak signal usualy used in audio amplifier.

The frequency response curve: It is graph between frequency and gain

Half-power points: These are the points where power becomes half to maximum power.

Band width: It is difference of frequencies of half-power points.

Transformer: It is device to increase or decrease the voltage which depends on turns on primary and secondary of transformer.

14.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

14.13 Viva-voce questions:

Question1. What is voltage gain?
Answer: It is the ratio of the output voltage to the input voltage.
Question2. Does the voltage gain depend on frequency?
Answer: Yes, at low and high frequency it is low and in mid frequency it is constant.
Question3. What is use of TC coupled amplifier?
Answer: This is used in power amplifier and impedance matching between stages of amplifier.
Question4. Why there is a kink on frequency response of TC coupled amplifier?
Answer: Due to resonance of input voltage to the LC circuit in transformer and capicitance
Question5. What is 3dB bandwidth?
Answer: 3 dB band width is difference of frequencies of half-power point.

Experiment 15: To draw characteristics of photoelectric cell

Structure

15.1Object:

After performing this experiment, you should be able to

- What is photoelectric cell?
- Characteristics of photoelectric cell?
- Uses of photoelectric cell

15.2Introduction:

A photoelectric cell is a device which converts light energy into electric energy. It works on the principle photo electric effect. Photo electric cells are three types.

(a) Photo-emissive cell
(b) Photo Voltaic cell
(c) Photo Conductive cell

The construction of Photo-emissive cell is following

Vacuum type: Vacuum type photo emissive cell consists of two electrodes, cathode and anode. The cathode is either V- shaped or semi cylindrical and is made of metal coated with emissive of alkaline metals. The anode is in the form of nickel or platinum wire facing the cathode. The two electrodes are sealed in a glass or quartz bulb

Gas filled. In Vacuum photoelectric cells, the current is very small. In order to increase this current the cell is filled with a suitable inter gas like helium, neon etc at a Pressure of 0.1 to 1 mm of mercury. The photo electron ionizes the gas and thus the current magnified. The drawback of gas filled photo electric cell is that the photo electric current does not vary linearly with the intensity of light. In our experiment we are using gas filled photo emissive cell.

15.3Apparatus Used:

Photo cell, volt meter (V), micro ammeter (μA), supply and a light source (incandescent lamp).

15.4Theory :

Photo emissive cell consists of two electrodes, called cathode and anode When light of frequency greater than he threshold frequency is incident on cathode, the electrons are emitted which are attracted by anode, so a current flows in the external circuit. This current depends on the intensity of incident radiation and anode potential. As the anode potential is increased, the current increases until saturation occurs.

According to Planck‟s quantum theory a photon of frequency has energy $h\nu$, when strike on metal plate (cathode), emits electrons. The kinetic energy of emitted electron is give by the following

$$KE = h\nu - w$$

Where 'h' is plank's constant and 'w' is the work function of the metal surface. Work function of metal is the minimum energy required to remove the electrons from the surface of the metal.

15.5About apparatus:

The apparatus is a circuit is presented in figure 1 & 2, which is a photocell. A battery is place between cathode and anode for providing voltage. Current is measured with the help of micro ammeter and voltage by voltmeter. A lamp is used to provide light which fall on surface of cathode.

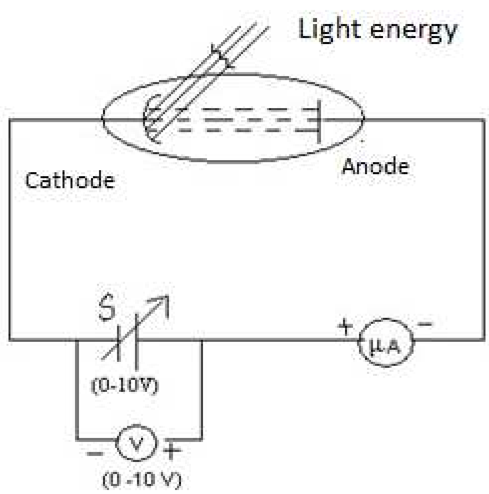


Figure 1: Circuit diagram of photoelectric cell for positive anode potential.

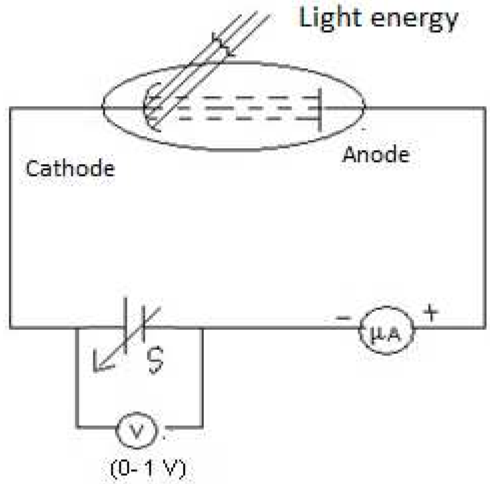


Figure 2: Circuit diagram of photoelectric cell for negative anode potential.

15.6Procedure:

Let us perform the experiment in following steps.

For positive anode potential:

46. Connect the circuit as shown in the figure 1.
47. Keep the source at the fixed distance from the photo cell
48. Note the reading of the ammeter at zero potential.
49. Now increase the positive anode potential in small steps till the reading in the ammeter reaches the maximum value.

For negative anode potential:

1. Connect the circuit as shown in the figure 2.
2. Keep the source at the fixed distance from the photo cell
3. Note the reading of the ammeter at zero potential.
4. Now increase the negative anode potential in small steps till ammeter reading becomes zero.

Plot a graph with +ve anode potential on the +ve X-axis and –ve anode potential on the-ve X-axis with the current on the +ve Y-axis.

15.7 Observation:

Table1. Cathode current for positive anode potential

SN	For intensity d=-----cm		For intensity d=-----cm		For intensity d=-----cm	
	+ve anode potential (V)	Current (μA)	+ve anode potential (V)	Current (μA)	+ve anode potential (V)	Current (μA)
1						
2						
3						
4						
5						
6						

Table2. Cathode current for negative anode potential

SN	For intensity d=-----cm		For intensity d=-----cm		For intensity d=-----cm	
	-ve anode potential (V)	Current (μA)	-ve anode potential (V)	Current (μA)	-ve anode potential (V)	Current (μA)
1						
2						
3						
4						
5						
6						

15.8Result:

The characteristics i.e. graph between anode potential and current is plotted.

15.9Precaution and source of error:

5. Sensitive voltmeter and sensitive ammeter sould be used.
6. The distance of the incandescent lamp from the photocell (cathode) should not be altered while taking the readings for a particular intensity.
7. The graphs should drawn smothly.
8. There should not be any fluctuation on the power.

15.10 Summary:

1. Photoelectric cell is works on the principle of photoelectric effect.
2. On increasing anode potential, the current increases up to saturation limit.
3. On increasing negative anode potential, the current stops and become zero for particular voltage. This voltage is called is stopping voltage.

15.11 Glossary:

Cathode: Electrode that emits electrons.

Anode: Electrode that attracts electrons emitted by cathode for current in outer circuit of cell.

Stopping potential: The stopping potential is the negative anode potential for which current become zero.

Work function: It is minimum electrical energy required to emit a electron from metal surface.

15.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

15.13 Viva-voce questions:

Question1. What is photoelectric effect?

Answer: Emission of electrons from the metal surface by the application of radiation is called photoelectric effect.

Question2. What is the stopping potential?

Answer: The stopping potential is the negative anode potential required to stop the most energetic electrons emitted by the cathode and reaching the anode.

Question3. What is the advantage of gas filled photo emissive ell over vaccum photo emissive cell?

Answer: In Vacuum photoelectric cells, the current is very small. In order to increase this current the cell is filled with a suitable inter gas like helium, neon etc at a Pressure of 0.1 to 1 mm of mercury. The photo electron ionizes the gas and thus the current magnified.

Question4. What is the range of the current in this experiment?

Question4: Define work function.

Answer: It is the minimum energy required to remove the electrons from the surface of the metal.

Question5. What is the value of planks constant ?

Answer: Its value is $6.6X10^{-34}$JS

Question6.What is Threshold frequency.

Answer: It is the minimum frequency of the incident radiation to start the photoelectric effect.

Experiment 16: To study of power supply

Structure

16.1 Object:

After performing this experiment, you should be able to

- What is power supply?
- How it is achieved?

16.2 Introduction:

For operating all the electronic circuits we always requires dc power. As we know AC is necessary for power transmission from one place to other, so we need to convert unregulated AC to constant dc. This conversion from AC to dc is called rectification and it is done by vacuum diode or pn junction diodes. For full wave rectification we need two vacuum diodes/pn junction diodes. Such converted dc have some ripples and it somehow made smooth with the help of filters. This work of converting an unregulated alternating current (AC) or voltage to a limited direct current (dc) or voltage to make the output constant regardless of the fluctuations in input, is done by a regulated power supply circuit.

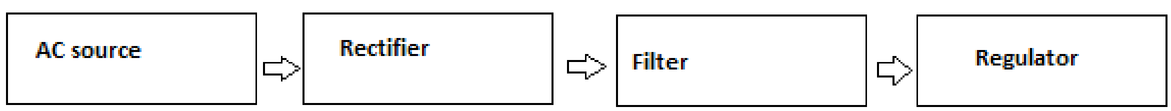


Figure 1

16.3 Apparatus Used:

D.C. voltage source (0-15V), voltmeter, ammeter, resistances and given network.

16.4 Theory and Formula Used:

For demand of dc, conversion of unregulated AC to constant dc is done by circuit called rectifiers. The output of rectifier have also AC component with dc, called ripple voltage. For getting smooth out, it is necessary to remove the ripples from output. For this L & π filters are used. The formula for voltage regulation and ripple factor is given

$$V_{regulation} = \frac{V_{NL} - V_L}{V_L(F)} \times 100$$

$$R\% = \frac{V_{AC}}{V_{dc}} \times 100$$

V_{NL}-Output voltage with no load, V_N-Output voltage with load, V_L(F)-Output voltage with full load R- Ripple factor,V_{AC} Output AC voltage and V_{dc} Output dc voltage

16.5 About apparatus:

The apparatus is a circuit for power supply shown in figure 2. The rectified output from bridge rectifier is send to the L & π filters to smooth the output. The CRO/VTVM is used for taking output.

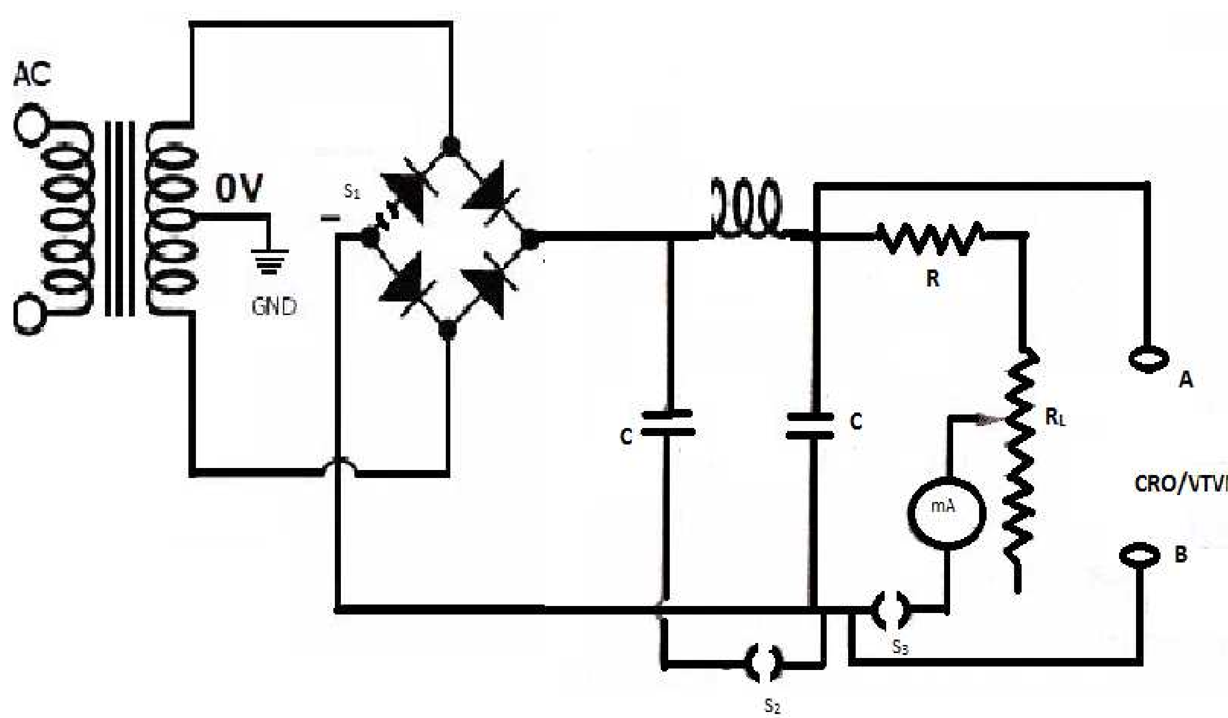


Figure 2: Circuit for the power supply.

16.6 Procedure:

For half wave rectifier **(S_1 open, S_2 open)** L section

1. Measure Voltage E_{NL} (S_2open) with the help of CRO/VTVM at no load.
2. Fixe the load value with help of potentiometer.
3. Close S_2, measure load current and load voltage E_L.
4. Measure dc load current and AC voltage

5. Repeat the observation for different load

For half wave rectifier **(S_1 open, S_2 close)** π section

1. Measure Voltage E_{NL} (S_2open) with the help of CRO/VTVM at no load.
2. Fixe the load value with help of potentiometer.
3. Close S_2, measure load current and load voltage E_L.
4. Measure dc load current and AC voltage
5. Repeat the observation for different load

For half wave rectifier **(S_1 close, S_2 open) L section**

6. Measure Voltage E_{NL} (S_2open) with the help of CRO/VTVM at no load.
7. Fixe the load value with help of potentiometer.
8. Close S_2, measure load current and load voltage E_L.
9. Measure dc load current and AC voltage
10. Repeat the observation for different load

For half wave rectifier **(S_1 close, S_2 close)** π section

6. Measure Voltage E_{NL} (S_2open) with the help of CRO/VTVM at no load.
7. Fixe the load value with help of potentiometer.
8. Close S_2, measure load current and load voltage E_L.
9. Measure dc load current and AC voltage
10. Repeat the observation for different load

16.7 Observation:

(A) Voltage with no load V_{NL}= ….. volt
(B) Table for voltage regulation

S.N.	Half wave rectifier S_1 open		Full wave rectifier S_1 close		Half wave rectifier S_1 open		Half wave rectifier S_1 open	
	L section	π section	L section	π section	L section	π section	L section	π section
1								
2								
3								
4								

5								

(C) For ripple factor (half wave rectifier)

S.N.	L section			π section		
	dc load current(mA)	V_{dc}	V_{AC}	dc load current(mA)	V_{dc}	V_{AC}
1						
2						
3						
4						
5						

(D) For ripple factor (Full wave rectifier)

S.N.	L section			π section		
	dc load current(mA)	V_{dc}	V_{AC}	dc load current(mA)	V_{dc}	V_{AC}
1						
2						
3						
4						
5						

16.8 Results:

(1) Voltage regulation % and ripple % are presented in following table (Half wave rectifier)

S.N.	dc load current (mA)	L section		π section	
		Voltage regulation %	Ripple %	Voltage regulation %	Ripple %
1					
2					
3					
4					
5					

(2) Voltage regulation % and ripple % are presented in following table (full wave rectifier)

S.N.	dc load current (mA)	L section		π section	
		Voltage regulation %	Ripple %	Voltage regulation %	Ripple %
1					
2					
3					
4					
5					

(3) Graph between dc output voltage and dc load current for L section & π section (half wave rectifier & full waver rectifier) are presented in graph.

16.9 Precaution and source of error:

51. Sensitive voltmeter and sensitive ammeter sould be used.
52. There should not be any fluctuation on the power.
53. To avoid over heating, current should not passed for long time.
54. The terminals of transformer should not touch directly.

16.10 Summary:

37. Power supply is circuit which convert AC voltage to dc voltage.
38. The power supply is a rectifier circuit followed by filter.
39. L or π section filters are used for regulation.
40. L or π section filter is better for regulation.

16.11 Glossary

` Power supply: Circuits that convert AC to dc.

Ripple: The AC component in rectifier output.

Filter: Circuits that remove ripples in output voltage.

Bridge rectifier: It combination of four pn junction forming bridge. It is better used for full wave

rectifier.

Transformer: It raise or voltage with cost of current. Output of transformer depends on turns of primary and secondary winding.

16.12 References:

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand publication, Delhi

2. C.L. Arora and P.S. Hemne, *Physics for Degree students (BSc Second year)*, S. Chand publication, Delhi

3. Indu Prakash, Ram Krishna, A K Jha, *A text Book of Practical Physics*, Kitab Mahal Publication Delhi.

5. S.L.Gupta, V.Kumar, *Practical Physics*, Pragati prakashan, Meerut.

4. *https://en.wikipedia.org.*

16.13 Viva-voce questions:

Question1. What is voltage regulation?

Answer: It is define the ability of rectifier to maintain a constant output with variation of load and input .

Question2. What is ripple voltage?

Answer: The AC component in the output of rectifier is called ripple voltage.

Question3.What are filter and why they used?

Answer: Filters are the electronic circuit which smoothen the output of rectifier.

Question4.Which is L or π section better for regulation?

Answer: L section.

Experiment 17: To study the logic gates

Structure:

17.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What are different gates?
- Draw electronic circuit of different gates.
- What is meant by truth table?

Also by performing the experimental part, you will be able to verify the truth table of different logic gates.

17.2 Introduction:

The main difference between analog and digital operation is the way the load line is used. With analog circuits, adjacent points on the load line may be used, so that the output voltage is continuous. Because of this, the output voltage can have an infinite number of values. One way to get analog operation is with a sinusoidal input. The continuously changing input voltage produces a continuously changing output voltage.

Digital circuits are different. Almost all digital circuits are designed for two-state operation. This means using only two adjacent points on the load line, typically saturation and cutoff. As a result, the output voltage has only two states (values), either low or high. One way to get digital operation is with square-wave input. If large enough, this type input drives the transistors into saturation and cutoff, producing a two-state output.

In digital systems two voltage levels represent the two binary digits, 1 and 0. If the higher of the two voltages represents a 1 and the lower voltage represents a 0, the system is called a positive logic system. On the other hand, if the lower voltage represents a 1 and the higher voltage represents a 0, we have a negative logic system.

In its basic form, ***logic*** is the realm of human reasoning that tells us a certain proposition (declarative statement) is true if certain conditions or premises are true. ‘The light is on’ is an example of a proposition that can be seen true or false.

Gates are digital circuits with one or more input voltages but only one output voltage. The most basic gates are called the NOT gate, the OR gate and the AND gate. By connecting these gates in different ways, we can build circuits that perform arithmetic and other functions associated with the human brain. Because they simulate mental processes, gates are often called ***logic circuits***.

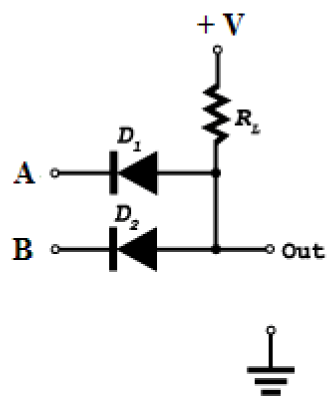
In this experiment we will see the output produced by different gates with respect to different input conditions.

17.3 Apparatus Used:

Digital logic training board with different logic gates and two toggle switches for input values (0 and 1), connection wires, voltmeter (or LED) for output measurement.

17.4 Theory and Formula Used:

AND gates: The AND gate has two or more input signals but only one output signal. The AND gate has a high output only when all inputs are high. Fig. 1(a) shows one way to build a 2-input AND gate using diodes. The input voltages are leveled A and B, while the output voltage is out. Let us assume a supply voltage V_{CC} of +5V. Also, we will assume that input voltages are either 0 V (low state) or +5 V (high state). There are only four possible cases:



(a)

(b)

A	B	Out
L	L	L
L	H	L
H	L	L
H	H	H

(c)

A	B	Out
0	0	0
0	1	0
1	0	0
1	1	1

(d)

Fig. 1. (a) Electronic circuit of 2- input AND gate (b) Symbol of AND gate (c) Output of 2- input AND gate (d) Binary equivalent of output

Case 1: A is low and B is low. With both input voltages low, the cathode of each diode is grounded. Therefore, the positive supply forward-biases both diodes in parallel. Because of this, the output voltage is ideally zero (to a second approximation, 0.7 V). This means out is low

Case 2: A is low and B is high. Since A is low, the upper diode is forward-biased, pulling the output down to a low voltage. With the B input high, the lower diode goes into reverse bias. Whether you use the ideal output (0 V) or the second approximation (+0.7 V), out is low.

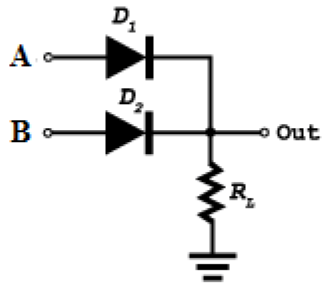
Case 3: A is high and B is low. Because of the symmetry of the circuit, the circuit operation is similar to case 2. The upper diode is off, the lower diode is on, and out is low.

Case 4: A is high and B is high. With both inputs at +5 V, both diodes are non-conducting because the voltage across each is zero. Since the diodes are off, there is no current through R_L, and the output is pulled up to the supply voltage (+5 V). Therefore, out is high.

Truth table is a table that shows all the input-output possibilities of a logic circuit. Fig. 1 (c) shows the truth table for an AND gate. Examine the table carefully and remembering the following: the AND gate has a high output only when A and B are high. In other words, the AND gate is an all-or-nothing gate; a high output occurs only when all inputs are high.

Because virtually all digital circuits are based on two-state operation, it is convenient to use binary numbers when troubleshooting, analyzing and designing digital system. In one approach, the binary digit 0 is the code for low voltage, and binary digit 1 is the code for high voltage. Fig. 1(d) is the binary equivalent of Fig. 1(c), where a binary 0 represents the low state, while a binary 1 stands for the high state.

OR gates: The OR gate has two or more input signals but only one output signal. It is called an OR gate because the output voltage is high if any or all of the input voltages are high. For instance, the output of 2-input OR gate is high if either or both inputs are high. Fig. 2(a) shows one way to build a 2-input OR gate using diodes. The input voltages are leveled A and B, while the output voltage is out. Let us assume that input voltages are either 0 V (low state) or +5 V (high state). There are only four possible cases:



(a)

(b)

A	B	Out
L	L	L
L	H	H
H	L	H
H	H	H

(c)

A	B	Out
0	0	0
0	1	1
1	0	1
1	1	1

(d)

Fig. 2. (a) Electronic circuit of 2- input OR gate (b) Symbol of OR gate (c) Output of 2-input OR gate (d) Binary equivalent of output

Case 1: A is low and B is low. With both input voltages low, the output voltage is low because both diodes are non-conducting. Therefore, out is low.

Case 2: A is low and B is high. The high B input voltage (+5 V) forward biases the lower diode, producing an output voltage that is ideally +5 V, or approximately +4.3 V including the diode voltage drop. Whether you use the ideal output (+5 V) or second approximation (+4.3 V), out is high. Note that upper diode is reverse-biased.

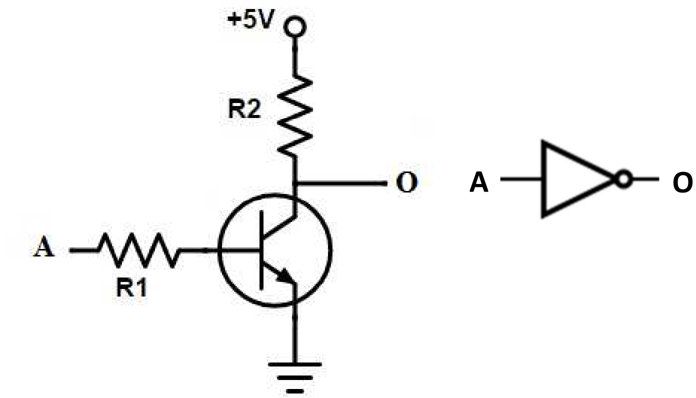
Case 3: A is high and B is low. Because of the symmetry of the circuit, the circuit operation is similar to case 2. The upper diode is on, the lower diode is off, and out is high.

Case 4: A is high and B is high. With both inputs at +5 V, both diodes are forward biased. Since the input voltages are in parallel, the output voltage is +5 V ideally (+4.3 V to a second approximation. Therefore, out is high.

Fig. 2 (c) is the truth table for an OR gate. Examine this table carefully and note the following: the OR gate has a high output when either A or B or both are high. In other words, the OR gate is any-or-all gate; an output occurs when any or all of the inputs are high. Fig. 2(d) is binary equivalent of Fig. 2(c).

NOT gates: Also called inverter, a gate with only one input and one output. It is called inverter because the output state is always opposite the input state. Specifically, when the input voltage is high, the output is low. On the other hand, when the input voltage is low, the output is high. Fig. 3 (a) is the circuit diagram of NOT gate. When input A is zero, the transistor cuts off and output O equals +5 V. When input A is high (+5 V), the transistor goes into saturation and output O is approximately zero. Since the input voltage can have only two values (0 or +5 V), the transistor operated only a cutoff or saturation. As a result, we get two state operation, which means the output voltage can have only two steady-state values (low or high). The symbol of NOT gate is shown in Fig. 3(b), and Fig. 3 (c) and (d) summarizes the operation of an inverter. A low input produces a high output, and a high input produces a low output.

:



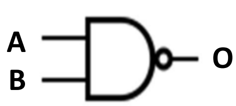
A	O
L	H
H	L

A	O
0	1
1	0

(a) (b) (c) (d)

Fig. 3. (a) Electronic circuit of NOT gate (b) Symbol of NOT gate (c) Output of NOT gate (d) Binary equivalent of output

NAND gates: When AND gate is combined with NOT gate in cascade, the resultant gate is known as NAND gate. Fig. 4 (a) shows the symbol of 2-input NAND gate. Because the circuit is an AND gate followed by an inverter, the only way to get a low output is for both inputs to be high as shown in Fig. 4 (b) and (c).



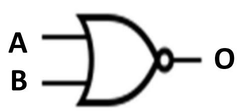
A	B	O
L	L	H
L	H	H
H	L	H
H	H	L

A	B	O
0	0	1
0	1	1
1	0	1
1	1	0

(a) (b) (c)

Fig. 4. (a) Symbol of NAND gate (b) Output of 2- input NAND gate (c) Binary equivalent of output

NOR gates: When OR gate is combined with NOT gate in cascade, the resultant gate is known as NOR gate. Fig. 5 (a) shows the symbol of 2-input NOR gate. With a NOR gate, all inputs must be low to get a high output. If any input is high, the output is low, as shown in Fig. 5 (b) and (c).



(a)

A	B	O
L	L	H
L	H	L
H	L	L
H	H	L

(b)

A	B	O
0	0	1
0	1	0
1	0	0
1	1	0

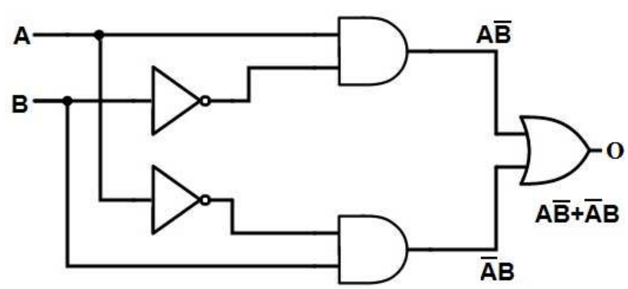
(c)

Fig. 5. (a) Symbol of NOR gate (b) Output of 2- input NOR gate (c) Binary equivalent of output

Exclusive OR (XOR) gates: An exclusive OR gate is shown in Fig. 6 (a) with its logic symbol in Fig. 1 (b). It has two inputs and one output. If the inputs be denoted by A and B then its output is given as:

$$O = A\overline{B} + \overline{A}B$$

Output of the XOR gate is shown in Fig. 6 (c) and (d).



(a)

(b)

A	B	Out
L	L	L
L	H	H
H	L	H
H	H	L

(c)

A	B	Out
0	0	0
0	1	1
1	0	1
1	1	0

(d)

Fig. 6. (a) An XOR gate (b) Symbol of XOR gate (c) Output of XOR gate (d) Binary equivalent of output

17.5 About Apparatus:

You will have a logic training board in which different gates will be available for experiments. Switches are available for inputs, 1 position of switch means; switch is in on condition and have +5V with respect to ground whereas 0 position of switch means; switch is in off condition and is in ground. So input can be given by means of these switches and output could be seen through voltmeter or LED, which are connected in between output of the gate and ground. If LED glows means the output is high (1) and if LED is off the output will be low (0). In case of voltmeter if the reading of the voltmeter is near to 5V, the output will be high (1) and if voltmeter shows zero reading the output will be low (0)

17.6 Procedure:

(i) Connect the circuit of AND gate as shown in fig. 7

(ii) Connect 0 – 0 input to gate. Observe the indicator and note down the output (according to whether voltmeter or LED is used).

(iii) Repeat the above procedure for different input combinations {(0, 1), (1, 0) and (1, 1), respectively and note down the corresponding output and form a truth table except NOT gate. In NOT gate there is only one input, so in truth table of NOT gate only two values for input is possible, i.e., 0 or 1.

(iv) Verify the observed truth table of AND gate with fig. 1(d).

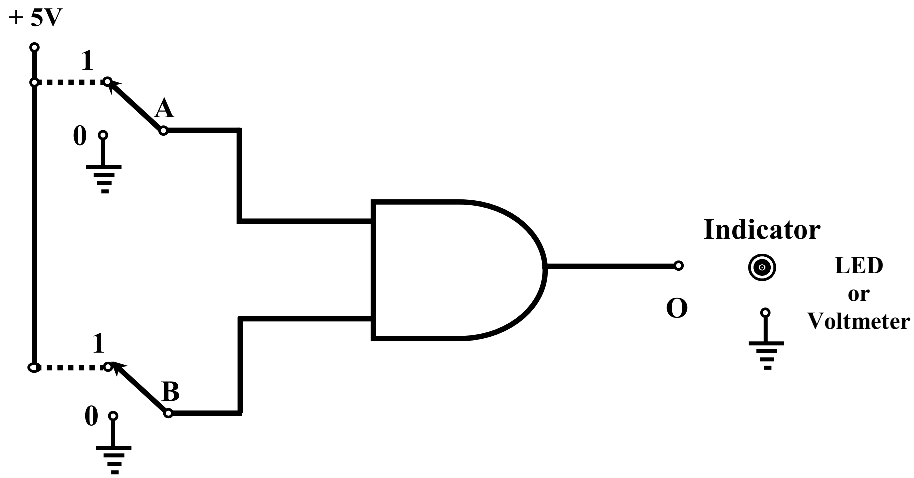


Fig.7 Connection for AND gate

(v) Similarly connect the circuit of OR, NOT, NAND, NOR and XOR gates as shown in figs. 8, 9, 10, 11 and 12 respectively. For different input combination note down the corresponding outputs for different gates and form truth table for each and every gate. Verify the observed truth table of OR, NOT, NAND, NOR and XOR gates with figs. 2(d), 3(d), 4(c), 5(c) and 6(d) respectively.

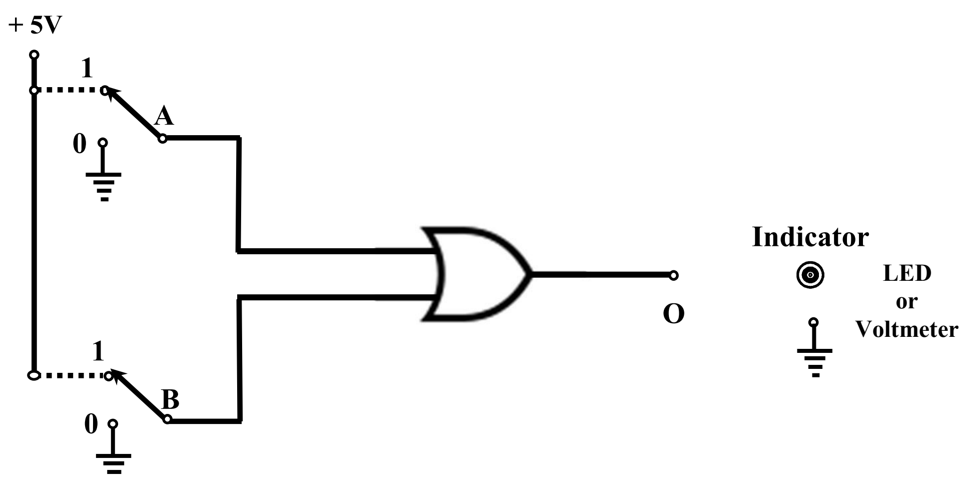


Fig.8 Connection for OR gate

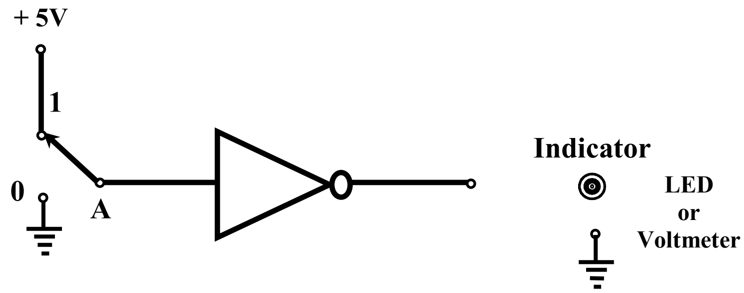


Fig.9 Connection for NOT gate

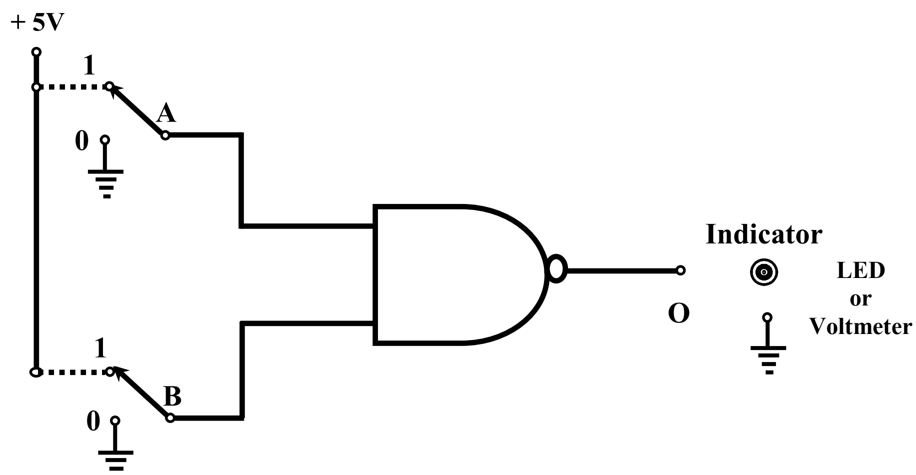


Fig.10 Connection for NAND gate

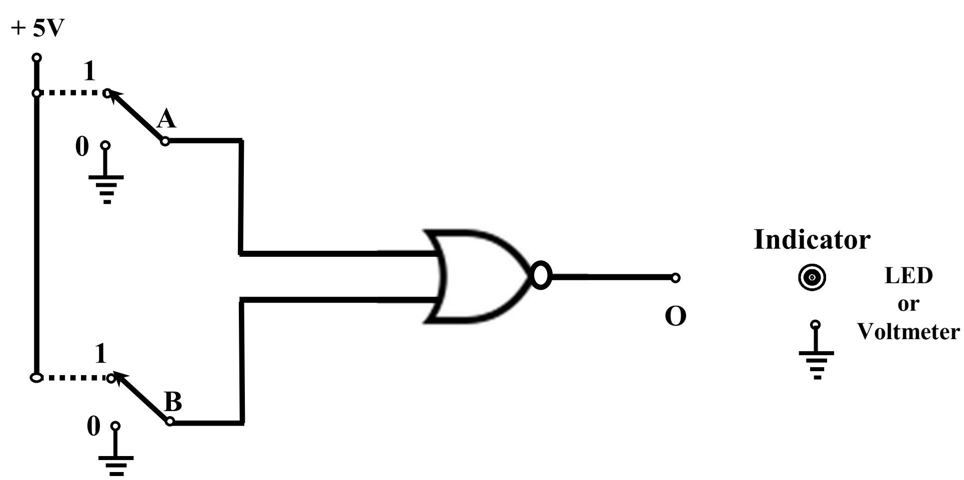


Fig.11 Connection for NOR gate

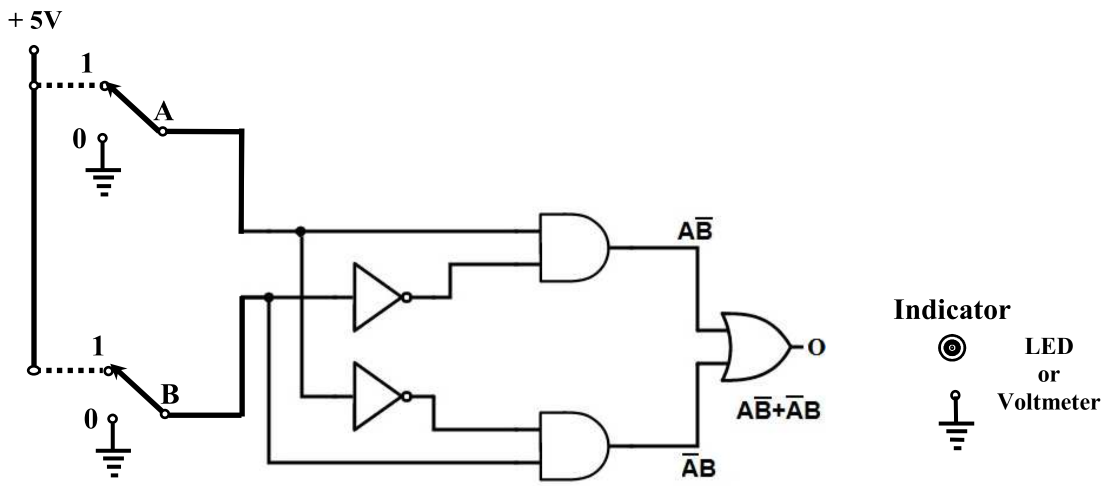


Fig.12 Connection for XOR gate

17.7 Observations:

The truth table observed for different gates (AND, OR, NOT, NAND, NOR and XOR) must be verify with figs.1(d), 2(d), 3(d), 4(c), 5(c) and 6(d) respectively.

17.8 Result: The observed truth table for different gates are the results.

17.9 Precautions and Source of Errors:

(i) Power supply to the various gates should be connected properly.

(ii) All the connections must be connected properly.

(iii) Make truth table for every gate separately.

17.10 Summary:

A digital device which has one or more inputs and only has one output is called gate. There are three basic gates in digital electronics; AND, OR and NOT gate. With the help of these gates, NAND, NOR and XOR gate can be fabricated. Giving different input combination {(0, 0), (0, 1), (1, 0), (1, 1)} for two input gates (except NOT gate) observed the output for respective combinations of each gate. NOT gate have only one input. With the help of truth table we can find the applications of different gates.

17.11 Glossary:

Gate:	A digital device which has one or more than one input but has only one output.
Truth table:	A table containing all the input combination and their respective outputs.
Binary digit system:	System that uses only two digits; 0 and 1.

17.12 References:

(i) '*Digital Principles and Applications*' by A.P. Malvino and D.P. Leach, Tata McGraw-Hill Publishing company Ltd.

(ii) '*Practical Physics*' Vol. II by S.L. Gupta and V. Kumar, Pragati Prakashan, Meerut.

17.13 Viva-voce questions and Answers

Q.1. Define analog and digital systems.

Ans. The main difference between analog and digital operation is the way the load line is used. With analog circuits, adjacent points on the load line may be used, so that the output voltage is continuous. Because of this, the output voltage can have an infinite number of values. One way to get analog operation is with a sinusoidal input. The continuously changing input voltage produces a continuously changing output voltage.

Digital circuits are different. Almost all digital circuits are designed for two-state operation. This means using only two adjacent points on the load line, typically saturation and cutoff. As a result, the output voltage has only two states (values), either low or high. One way to get digital operation is with square-wave input. If large enough, this type input drives the transistors into saturation and cutoff, producing a two-state output.

Q.2. What is meant by logic gate?

Ans. A digital device which has one or more inputs and has only one output is called logic gate**.** Because they simulate mental processes, gates are often called ***logic circuits***.

…………….O…………….

Experiment 18: To verify truth table of adder and subtractor

Structure:

18.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What are half and full adder?
- What are half and full subtractor?

Also by performing the experimental part, you will be able to design half and full adder and half and full subtractor.

18.2 Introduction:

By combining logic gates in the right way, we can build circuits that add and subtract. Since these circuits are electronic, they are fast. Typically, an addition is done in microseconds. In this experiment we will verify the truth table of half and full adder and subtractor using logic gates.

18.3 Apparatus Used:

Digital logic training board with different logic gates (2 - AND, 2 - OR, 2 – XOR and 1 – NOT) and three toggle switches for input values (0 and 1), connection wires, voltmeter (or LED) for output measurement.

18.4 Theory and Formula Used:

Half-adder: When we add two binary numbers, we start with the least-significant column. This means that we have to add two bits with the possibility of a carry. The circuit used for this is called a ***half adder***. Fig. 1 shows how to build a half adder. The output of the exclusive-OR gate is called the ***SUM***, while the output of the AND gate is the ***CARRY***. The AND gate provide high output only when both inputs are high. The exclusive-OR gate produces a high output if either input, but not both, is high. Table – 1 shows the truth table of a half adder.

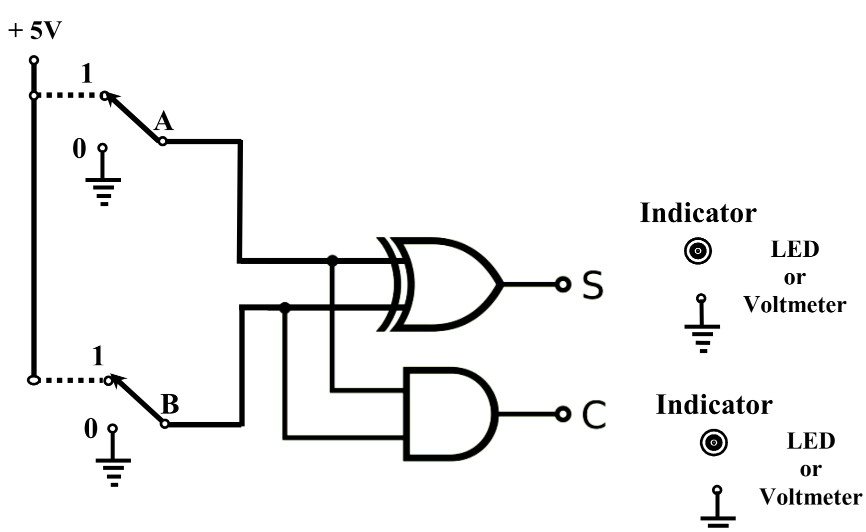


Fig. 1 Logic circuit of Half Adder

Table - 1 ***Half Adder Truth Table***

A	*B*	*CARRY*	*SUM*
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

When you examine each entry in Table – 1, you are struck by the fact that a half adder performs binary addition. It does electronically what we do mentally when we add 2 bits. Here is the action, entry by entry:

First Entry –
Input: A= 0 and B = 0
Human response: 0 plus 0 is 0 with a carry of 0
Half-adder response: SUM = 0 and CARRY = 0

Second Entry –
Input: A= 0 and B = 1
Human response: 0 plus 1 is 1 with a carry of 0
Half-adder response: SUM = 1 and CARRY = 0

Third Entry –
Input: A= 1 and B = 0
Human response: 1 plus 0 is 1 with a carry of 0
Half-adder response: SUM = 1 and CARRY = 0

Fourth Entry –
Input: A= 1 and B = 1
Human response: 1 plus 1 is 0 with a carry of 1
Half-adder response: SUM = 0 and CARRY = 1

As you see, the half-adder mimics our brain processes in adding bits. The only difference is the half-adder is about a million times faster than we are.

Full-Adder: For the higher-order, we have to use a full-adder, a logic circuit that can add 3 bits at a time. The third bit is the carry from a lower column. This implies that we need a logic circuit with three inputs and two outputs, similar to the half-adder in Fig. 2. (Other designs are possible).
Table – 2 shows the truth table of a full-adder. You can easily check this truth table for its validity. When you examine each entry in Table – 2, you can see that a full adder performs

binary addition on 3 bots. Here is the action of some selected entries to illustrate the similarity between human data processing and electronic data processing:

First Entry –
Input: A= 0, B = 0 and C = 0
Human response: 0 plus 0 plus 0 is 0 with a carry of 0
Full-adder response: SUM = 0 and CARRY = 0

Second Entry –
Input: A= 0, B = 0 and C = 1
Human response: 0 plus 0 plus 1 is 1 with a carry of 0
Half-adder response: SUM = 1 and CARRY = 0

Fourth Entry –
Input: A= 0, B = 1 and C = 1
Human response: 0 plus 1 plus 1 is 0 with a carry of 1
Half-adder response: SUM = 0 and CARRY = 1

Last Entry –
Input: A= 1, B = 1 and C = 1
Human response: 1 plus 1 plus 1 is 1 with a carry of 1
Half-adder response: SUM = 1 and CARRY = 1

Table - 2 ***Full Adder Truth Table***

A	*B*	*C*	*CARRY*	*SUM*
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

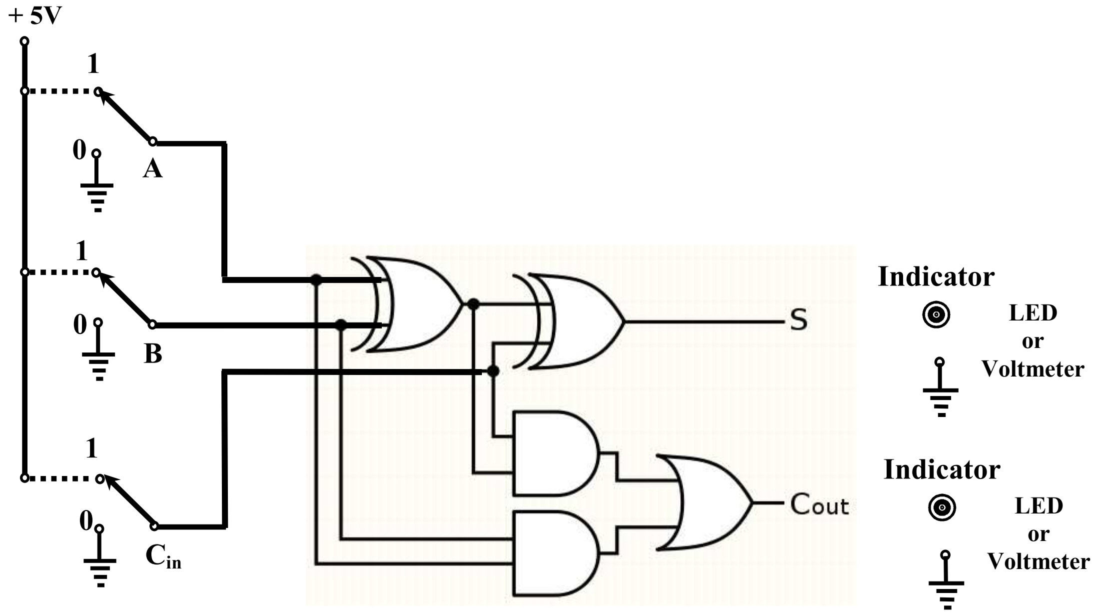


Fig. 2 Logic circuit of Full Adder

So you can see, the full-adder captures in electronic circuitry those brain processes that we use when adding three bits at a time. The full-adder can do more than a million additions per second. Besides that, it never gets tired or bored, or asks for a raise

Half-Subtractor: It can subtract two digits at a time and produce an output of a difference and a borrow.

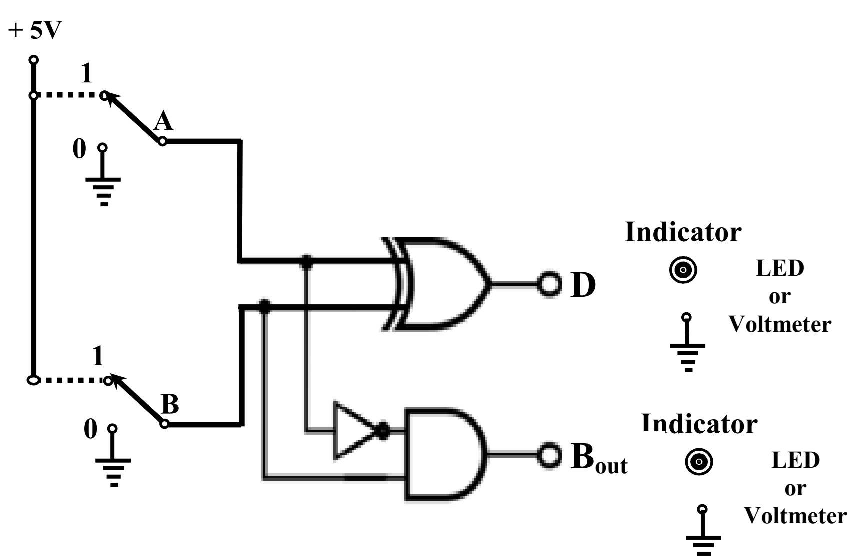


Fig. 3 Logic circuit of Half Subtractor

Fig. 3 shows how to build a half subtractor. The output of the exclusive-OR gate is called the ***DIFFERENCE***, while the output of the AND gate is the ***BORROW***. The AND gate provide high output only when inputs; A = 0 and B = 1. The exclusive-OR gate produces a high output if either input, but not both, is high. Table – 3 shows the truth table of a half subtractor.

Table - 3 ***Half Subtractor Truth Table***

A	*B*	*BORROW*	*DIFFERENCE*
0	0	0	0
0	1	1	1
1	0	0	1
1	1	0	0

Similar to the half-adder and full-adder you can check the truth table with logic circuit of half subtractor, entry by entry.

Full-Subtractor: It can subtract three digits at a time and produce an output of a difference and a borrow (actually, in full subtractor the borrow from the subtraction process of the previous stage, denoted by C, is one of the inputs, A is minuend and B is subtranhend).

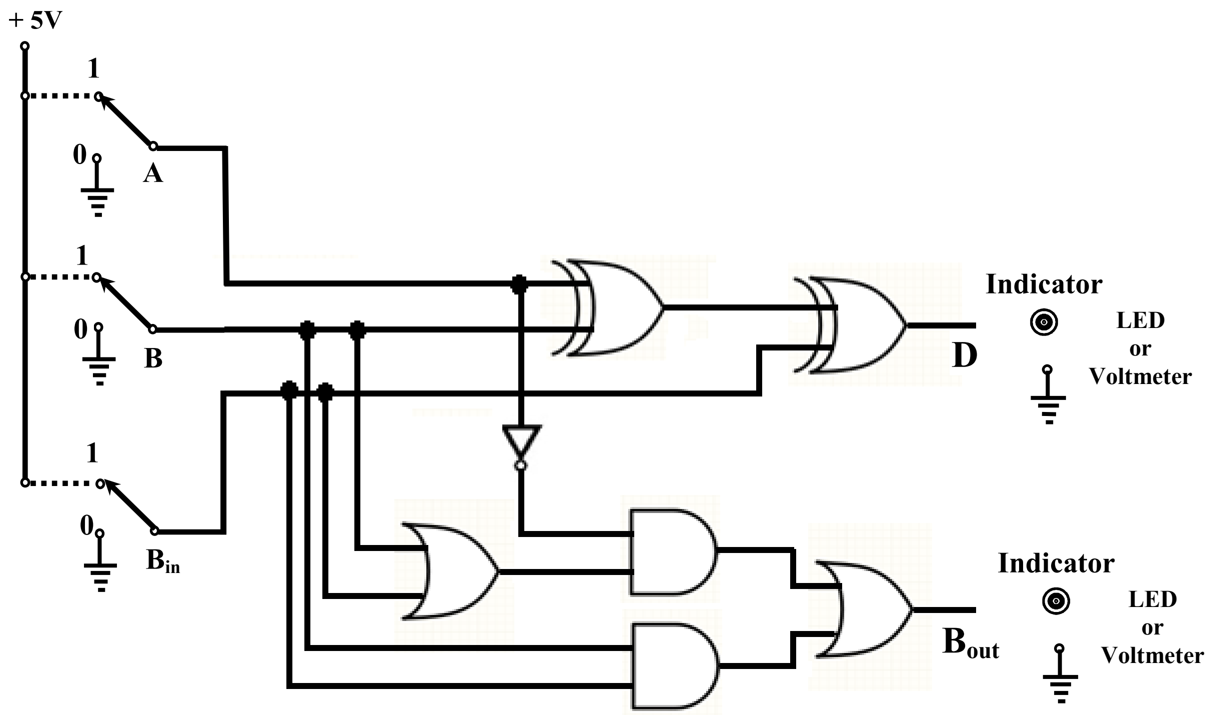


Fig. 4 and Table – 4 shows the circuit diagram and truth table, respectively, of a full subtractor.

Table - 2 ***Full Adder Truth Table***

A	*B*	*C*	*BORROW*	*DIFFERENCE*
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	1	0
1	0	0	0	1
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

18.5 About Apparatus:

You will have a logic training board in which different gates will be available for experiments. Switches are available for inputs, 1 position of switch means; switch is in on condition and have +5V with respect to ground whereas 0 position of switch means; switch is in off condition and is in ground. So input can be given by means of these switches and output could be seen through voltmeter or LED, which are connected in between output of the gate and ground. If LED glows means the output is high (1) and if LED is off the output will be low (0). In case of voltmeter if the reading of the voltmeter is near to 5V, the output will be high (1) and if voltmeter shows zero reading the output will be low (0)

18.6 Procedure:

(i) Connect the circuit of half –adder as shown in fig. 1

(ii) Connect 0 – 0 input to gate. Observe the indicator and note down both the output (SUM and CARRY). (according to whether voltmeter or LED is used).

(iii) Repeat the above procedure for different input combinations {(0, 1), (1, 0) and (1, 1), respectively and note down the corresponding outputs and form a truth table.

(iv) Verify the observed truth table of half-adder with Table- 1.

(v) Similarly connect the circuit of full-adder, half-subtractor and full-subtractor as shown in figs. 2, 3 and 4 respectively. For different input combination note down the corresponding outputs for different circuits and form truth table for each and every circuit (full-adder, half-subtractor and full-subtractor). Verify the observed truth table of half-adder, full-adder, half-subtractor and full-subtractor with the truth tables 1, 2, 3 and 4 respectively.

18.7 Observations:

The truth table observed for different circuits (half-adder, full-adder, half-subtractor and full-subtractor) must be verify with truth tables 1, 2, 3 and 4 respectively.

18.8 Result: The observed truth tables for different circuits are the results.

18.9 Precautions and Source of Errors:

(iv) Power supply to the various circuits should be connected properly.

(v) All the connections must be connected properly.

(vi) Make truth table for every circuit separately.

18.10 Summary:

Half adder adds two binary digits at a time and thus is a basic circuit for adders and full-adder adds three bits at a time. Similarly half subtractor subtracts two bits and full-subtractor subtracts three bits at a time. Giving different input combination {(0, 0), (0, 1), (1, 0), (1, 1)} for half-adder and subtractor observed the output for respective circuits. Similarly output of the full-adder and subtractor can be observed from the respective circuits.

18.11 Glossary:

Half-adder: Circuit which adds two digits at a time.

Full-adder: Circuit which adds three digits at a time.

Half-subtractor: Circuit which subtract two digits at a time.

Full-subtractor: Circuit which subtract three digits at a time.

Truth table: A table containing all the input combination and their respective outputs.

Binary digit system: System that uses only two digits; 0 and 1.

18.12 References:

(1) '*Digital Principles and Applications*' by A.P. Malvino and D.P. Leach, Tata McGraw-Hill Publishing company Ltd.

(2) '*Practical Physics*' Vol. II by S.L. Gupta and V. Kumar, Pragati Prakashan, Meerut.

18.13 Viva-voce questions and Answers:

Q. 1 What is meant by half-adder?

Ans. A logic circuit with two inputs and two outputs, it adds two bits at a time, producing a sum and a carry output.

Q.2 What is meant by full-adder?

Ans. A logic circuit with three inputs and two outputs, it adds three bits at a time, giving a sum and a carry output.

Q. 3 What is meant by half and full-subtractor?

Ans. A logic circuit that subtract two digits at time is called half-subtractor and the circuit which subtract three digits at a time is called fill-subtractor. Both the circuits gives two outputs one is difference and other is borrow.

……………O……………

Experiment 19: Study of Cathode Ray Oscilloscope (CRO)

Structure:

19.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What is meant by CRO?
- How does CRO works?

Also by performing the experimental part, you will be able to find out the value of frequency, phase, and voltage of any signal with the help of CRO.

19.2 Introduction:

The cathode ray oscilloscope (commonly abbreviated as CRO) is an electronic device which is capable of giving a visual indication of a waveform. No other instrument used in the electronic industry is as versatile as the cathode ray oscilloscope. It is widely used for trouble shooting radio and television receivers as well as for laboratory works involving research and design. With an oscilloscope, the wave-shape of a signal can be studied with respect to amplitude distortion and deviation from the normal. In addition, the oscilloscope can also be used for measuring voltage, frequency and phase shift.

In an oscilloscope, the electrons are emitted from a cathode accelerated to a high velocity, and brought to focus on a fluorescent screen. The screen produces a visible spot where the electron beam strikes. By deflecting the electron beam over the screen in response to the electrical signal, the electron can be made to act as an ***electrical pencil of light*** which produces a spot of light wherever it strikes. An oscilloscope obtains its remarkable properties as a measuring instrument from the fact that it uses as an indicating needle a beam of electrons. As electrons have negligible mass, therefore, they respond almost instantaneously when acted upon by an electrical signal and can trace any electrical variation no matter how rapid.

19.3 Apparatus Used:

Variable audio frequency generator, cathode ray oscilloscope and an R-C circuit

19.4 Theory and Formula Used:

A cathode ray oscilloscope contains a cathode ray tube and necessary power equipment to make it operate.

Cathode ray tube*:** A cathode ray tube (commonly abbreviated as CRT) is the heart of the oscilloscope. It is a vacuum tube of special geometrical shape and converts an ***electrical signal into visual one. A CRT makes available plenty of electrons. These electrons are accelerated to high velocity and are brought to focus on a fluorescent screen. The electron beam produces a spot of light wherever it strikes. The electron beam is deflected on its journey in response to the electrical signal under study. The result is that electrical signal waveform is displayed visually. Fig. 1 shows the various parts of CRT.

i. ***Glass envelope***: It is conical highly evacuated glass housing and maintains vacuum inside and supports the various electrodes. The inner walls of CRT between neck and screen are usually coated with a conducting material, called ***aquadag***. This coating is electrically connected to the accelerating anode so that electrons which accidently strike the walls are returned to the anode. This prevents the walls of the tube from charging to a high negative potential.

ii. ***Electron gun assembly***: The arrangement of electrodes which produce a focused beam of electrons is called the electron gun. It essentially consists of an indirectly heated cathode, a control grid, a focusing anode and an accelerating anode. The control grid is held at negative potential with respect to cathode whereas the two anodes are maintained at high positive with respect to cathode.
The cathode consists of a nickel cylinder coated with oxide coating and provides plenty of electrons. The control grid encloses the cathode and consists of a metal cylinder with a tiny circular opening to keep the electron beam small in size. The focusing anode focuses the electron beam into a sharp pin-point by controlling the positive potential on it. The positive potential (about 10 kV) on the accelerating anode is much higher than on the focusing anode. For this reason, this anode accelerates the narrow beam to a high velocity. Therefore, the electron gun assembly forms a narrow, accelerated beam of electrons which produces a spot of light when it strikes the screen.

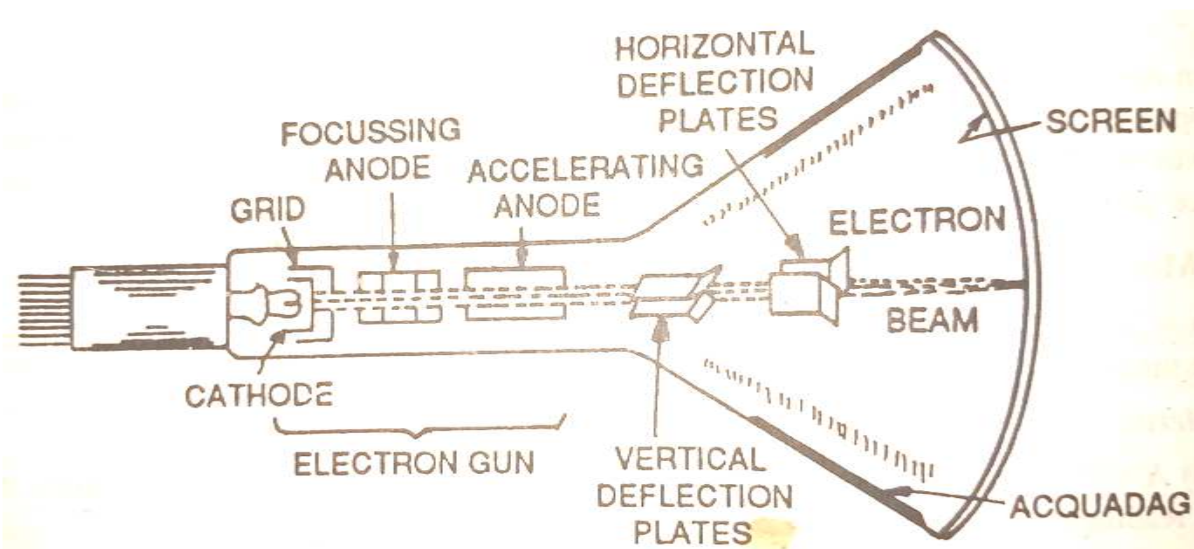


Fig. 1. Part-wise diagram of cathode ray tube (CRT)

iii. ***Deflection plate assembly***: The deflection of the beam is accomplished by two sets of deflecting plates placed within the tube beyond the accelerating anode as shown in Fig. 1. One set is the **vertical deflection *plates*** and the other set is the **horizontal deflection plates**.

The vertical deflection plates are mounted horizontally in the tube. By applying proper potential to these plates, the electron beam can be made to move up and down vertically on the fluorescent screen. The horizontal deflection plates are mounted in the vertical plane. An appropriate potential on these plate can cause the electron beam to move right and left horizontally on the screen.

iv ***Screen***: The screen is the inside face of the tube and is coated with some fluorescent material such as zinc ortho-silicate, zinc oxide etc. When high velocity electron beam strikes the screen, a spot of light is produced at the point of impact. The color of the spot depends upon the nature of fluorescent material. If zinc ortho-silicate is used as the fluorescent material, green light spot is produced.

Action of CRT: When the cathode is heated, it emits plenty of electrons. These electrons pass through control grid on their way to screen. The control grid influences the amount of current flow as in standard vacuum tubes. If negative potential on the control grid is high, fewer electrons will pass through it and the electron beam on striking the screen will produce a dim spot of light. Reverse will happen if the negative potential on the control grid is reduced. Thus, the intensity of the light spot on the screen can be changed by changing the negative potential on the control grid. As the electron beam leaves the control grid, it comes under the influence of focusing and accelerating anodes. As the two anodes are maintained at high positive potential, therefore, they produces a field which acts as an electrostatic lens to converge the electron beam at a point on the screen.

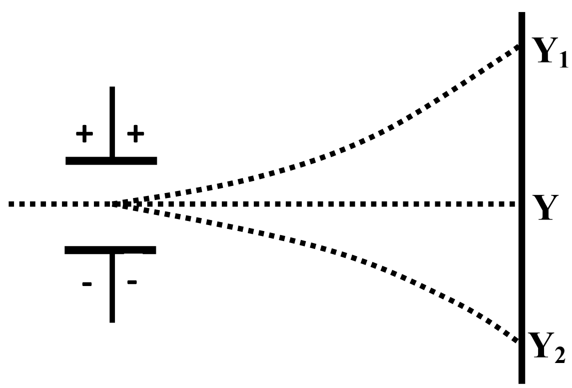


Fig. 2

As the electron beam leaves the accelerating anode, it comes under the influence of vertical and horizontal deflection plates. If no voltage is applied to the deflection plates, the electron beam will produce spot of light at the centre (Point Y in Fig. 2). If the voltage is applied to vertical plates only, the electron beam and hence the spot of light will deflected upwards (point Y_1 in Fig. 2). The spot of light will be deflected downwards (Point Y_2 in Fig. 2) if the potential on the plates reversed. Similarly the spot of light can be moved horizontally by applying voltage across the horizontal plates.

Deflection sensitivity of CRT: The shift of the spot of light on the screen per unit change in voltage across the deflection plates is known as ***deflection sensitivity*** of CRT. For instance, if a voltage of 100 V applied to the vertical plates produces a vertical shift of 3 mm in the spot, then deflection sensitivity is 0.03 mm/V. In general,

Spot deflection = Deflection sensitivity × Applied voltage

The deflection sensitivity depends not only on the design of the tube but on the voltage applied to the accelerating anode. The deflection sensitivity is low at high accelerating voltages and vice-versa.

19.5 About Apparatus:

Circuit is shown in Fig. 3. Some controls on CRO front panel are shown in Fig. 4. On vertical scale divisions, use Volt/Div and find amplitude, on horizontal scale divisions, use Time/Div and find time and hence frequency.

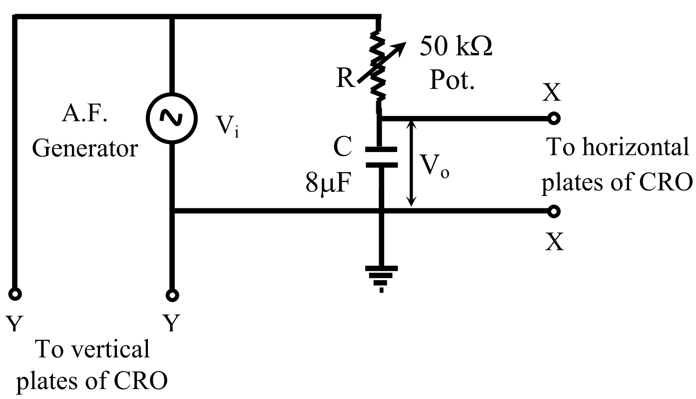


Fig. 3 RC network with its connection with CRO and AF oscillator

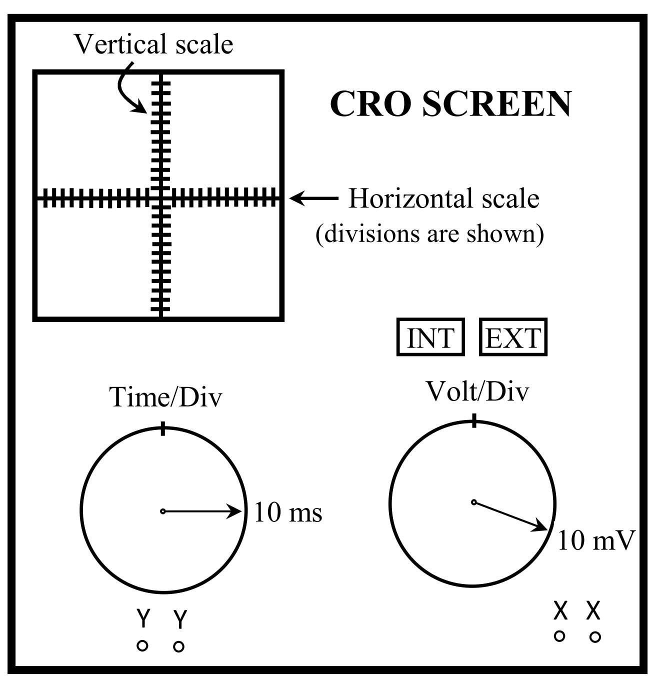
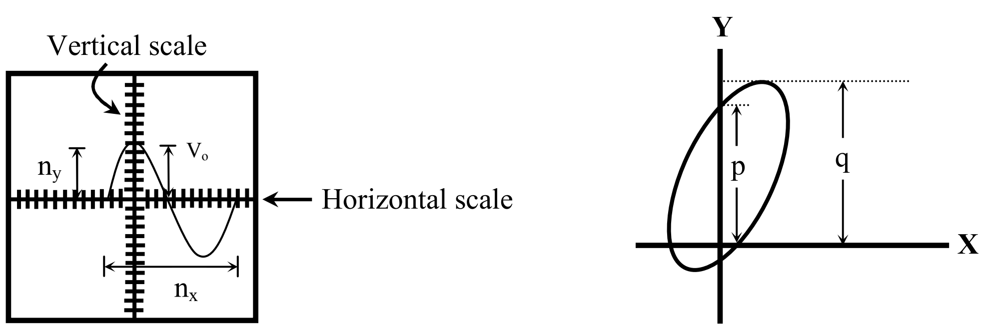


Fig. 4 Front panel of CRO

19.6 Procedure:

(a) To measure output voltage, V_o and frequency of input voltage:

(i) Connect audio frequency generator to RC network.
(ii) Connect X-X terminal to the horizontal plates of CRO.
(iii) Use INT synchronization control of CRO.
(iv) By adjusting output of audio frequency generator, V_i (both amplitude and frequency control terminals) and frequency of INT.SYN terminal, obtain a stable waveform on the CRO screen (Fig. 5a). Using VTVM, measure, input voltage V_i.
(v) Read number of divisions in the peak value V_o of voltage on the vertical scale of CRO. Using Volt/Div value find V_o. For example, say Volt/Div indicator is at 10 mV and we get n_y division corresponding to V_o on vertical scale then $V_o = n_y \times 10$ mV (Fig. 4a). ***Similarly one can find out the value of DC voltage.***
(vi) To measure frequency, note the number of divisions on horizontal scale in one complete cycle of waveform on the screen. Suppose number of divisions are n_x and Time/Div control indicator of CRO is on 10 ms, then period of wave, $T = n_x \times 10$ ms. Then (1/T) will give the frequency.



(a) **(b)**

Fig. 5

(b) To measure phase angle (ϕ):

(i) Cut off INT.SYN. control of CRO and use EXT.SYN.
(ii) Connect X-X terminals to horizontal plates and Y-Y terminals to vertical plates of CRO (i.e., V_i to vertical plates and V_o to horizontal plates).
(iii) A waveform shown in Fig. 5(b) is obtained. Measure p and q by noting number of divisions on vertical scale and then by multiplying by Volt/Div value.
(iv) Find phase $\phi = \tan^{-1}(p/q)$

Experiment can be repeated for other frequencies of input voltage.

19.7 Observations:

Frequency of AF Generator	Amplitude (V_o)		Frequency (f = 1/T)		Phase (ϕ)		
	n_y	$V_o = n_y \times$ (Volt/Div) value	n_x	$T = n_x \times$ (Time/Div) value	p	q	ϕ
f_1	----	----	----	----	----	----	----
f_2	----	----	----	----	----	----	----
f_3	----	----	----	----	----	----	----

19.8 Result:

(i) Amplitude: Theoretical value

$$V_o = \frac{V_i}{1+\omega^2 C^2 R^2} = \text{........Volt}$$

Experimental value = …… Volt

(ii) Frequency: Directly from AF generator = …… Hz

experimental value = …… Hz

(iii) Phase: Theoretical value $\phi = \tan^{-1}(\omega CR)$ = …… deg.

Experimental value ϕ = …… deg.

$$\text{Percentage error} = \frac{\text{experiment al value} \sim \text{Theoretica l value}}{\text{standard value}} \times 100$$

= …….. %

19.9 Precautions and Source of Errors:

(i) Keep the intensity of waveform moderate on screen.

(ii) Use such a value of Volt/Div and Time/Div that nearly the full scales on CRO screen are used. Waveform should be large so as to be on full screen.

(iii) Reactance of capacitance, C, should be much smaller than the input impedance of CRO.

19.10 Summary:

Cathode ray Oscilloscope is a device which converts electrical signal into visual one. It is very useful in the measurement of frequency, voltages (DC & AC), Phase etc. With this experiment we come to know how these quantities are measured through CRO.

19.11 Glossary:

CRO: Cathode ray oscilloscope, which convert electrical signal into visual one.

Aquadag: This is conducting material, which is coated to inner wall of CRT. This coating is electrically connected to the accelerating anode so that electrons which accidently strike the walls are returned to the anode. This prevents the walls of the tube from charging to a high negative potential.

Deflection sensitivity of CRT: The shift of the spot of light on the screen per unit change in voltage across the deflection plates is known as *deflection sensitivity* of CRT.

Screen: The screen is the inside face of the Cathode ray tube and is coated with some fluorescent material such as zinc ortho-silicate, zinc oxide etc.

19.12 References:

(iii) '*Principles of Electronics*' by V.K. Mehta, S. Chand & Company Ltd.

(iv) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.

19.13 Viva-voce questions and Answers:
(*Read the theoretical part of this experiment*)

……………O……………

Experiment 20: Study of He-Ne Laser (To Determine the Wavelength of He-Ne Laser Using Diffraction Grating)

Structure:

20.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What is meant by Laser?
- Draw energy level diagram of He-Ne laser?
- What is meant by diffraction grating?

Also by performing the experimental part, you will be able to find out the value of wavelength of He-Ne laser using diffraction grating.

20.2 Introduction:

He-Ne laser is a four energy level laser, one in helium and three in neon. The excitation of helium and neon atoms is obtained by means of high frequency electromagnetic field. The energy is transferred to the atoms of the gas by electron impact and collisions between atoms. In this experiment diffraction grating has been used to find out the wavelength of He-Ne laser.

20.3 Apparatus Used:

Diffraction grating with mount, microscopic objective (MO), He-Ne laser, millimeter graph sheet to be used as screen, optical bench.

20.4 Theory and Formula Used:

Laser is an abbreviation of '***light amplification by stimulated emission of radiation***', and symbolically suggests that the process of stimulated emission of radiation is used to amplify light. It is a device for producing very intense, almost unidirectional, monochromatic and coherent visible light beams.

He-Ne is a four-level laser in which the population inversion is achieved by electric discharge. A mixture of about 7 parts of helium and 1 part of neon is contained in a glass tube at a pressure of about 1 mm of mercury (Fig. 1). At both ends of the tube are fitted optically plane and parallel mirrors, one of them being only partially silvered, so that laser beam when sufficiently built leaks through it to serve as output laser beam. The spacing of the mirrors is equal to an integral number of half-wavelengths of the laser light. An electrical discharge is produced in the gas-mixture by electrodes connected to a high-frequency electric source.

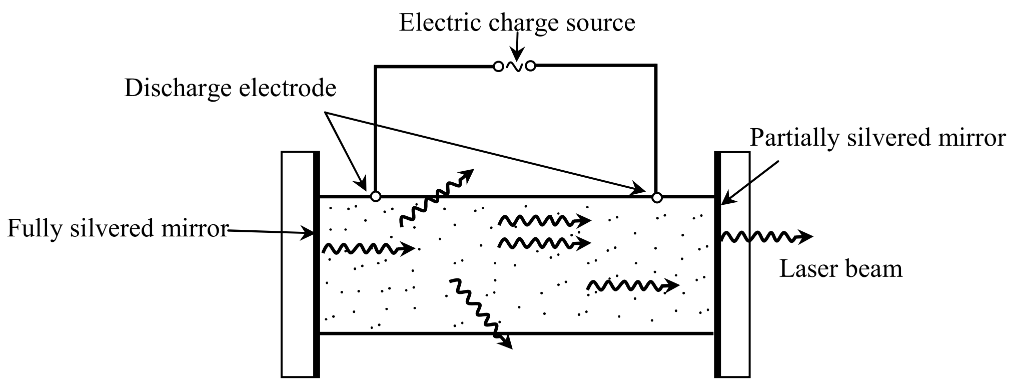


Fig. 1 Construction detail of He-Ne laser

The electrons from the discharge collide with and ***pump*** (excite) the He and Ne atoms to meta-stable state 20.61 eV and 20.66 eV respectively above their ground states (Fig. 2). Some of the excited He atoms transfer their energy to ground state Ne atoms by collisions, with the 0.05 eV of additional energy being provided by the kinetic energy of the atoms. (The advantage of this collision process is that the lighter He atoms can be easily pumped up to their excited states; the much heavier Ne atoms could not be raised efficiently without them). Thus He atoms help in achieving a population inversion in the Ne atoms.

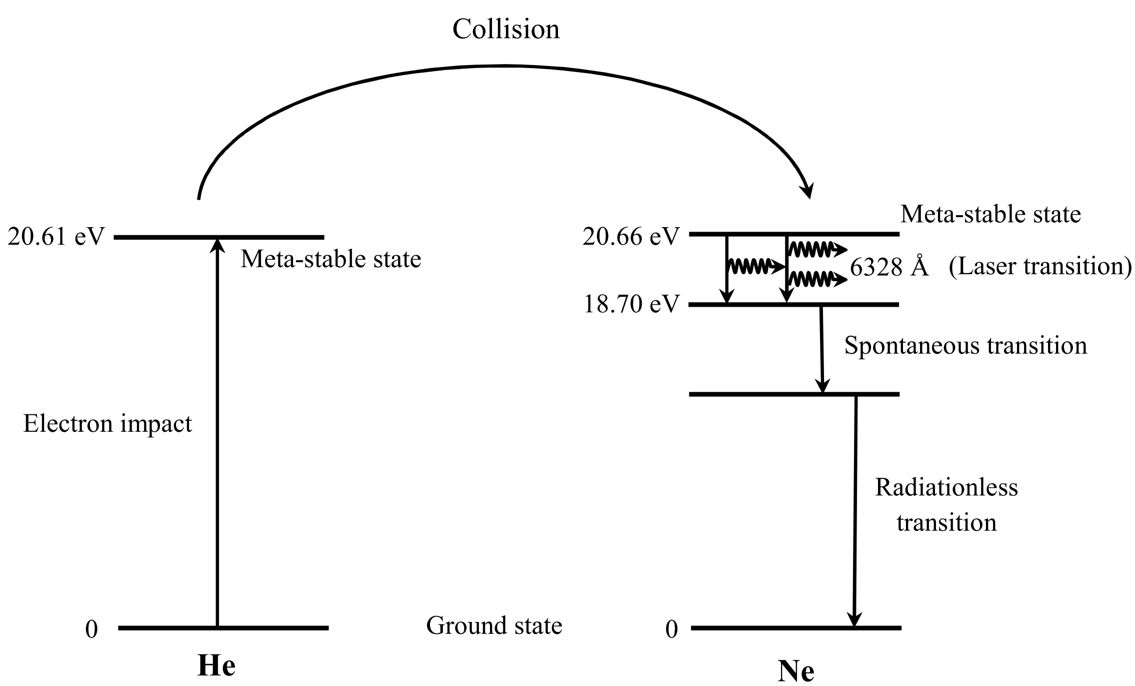


Fig. 2 Four – level He-Ne- laser

When an excited Ne atom passes spontaneously from the meta-stable state at 20.66 eV to state at 18.70 eV, it emits a 6328 Å photon. This photon travels through the gas mixture, and if it is moving parallel to the axis of the tube, is reflected back and forth by the mirror-ends until it stimulates an excited Ne atom and cause it to emit a fresh 6328 Å photon in phase with the stimulating photon. This stimulating transition from 20.66 eV level to 18.70 eV level is the laser transition. This process is continued and a beam of coherent radiation builds up in the tube. When this beam becomes sufficiently intense, a portion of it escapes through the partially-silvered end. From the 18.70 eV level the Ne atom passes down spontaneously to a lower meta-stable state emitting incoherent light and finally to the ground state through collision with the tube walls. The final transition is thus radiationless. The electron impacts that excite the He and Ne atoms occur all the time, unlike the pulsed excitation from the xenon flash lamp in the Ruby laser, the He-Ne laser operates continuously.

Now, a diffraction grating is an arrangement equivalent to a large number of parallel slits of equal widths and separated from one another by equal opaque spaces. It is made by ruling a large number of fine, equidistant and parallel lines on an optically-plane glass plate with a diamond point. The rulings scatter the light and are effectively opaque while the un-ruled parts transmit light and act as slits. Let MN (Fig. 3) be the section of a plane transmission grating, the length of the slit being perpendicular to the plane of the paper. Let e be the width of each slit and d the width of each opaque space between the slits. Then (e + d) is called grating element, the points in two consecutive slits separated by the distance (e + d) are called the 'corresponding points'.

The principle maxima in the grating spectrum are obtained in the directions given by –

$$\mathbf{(e + d)\sin\theta = n\lambda}$$

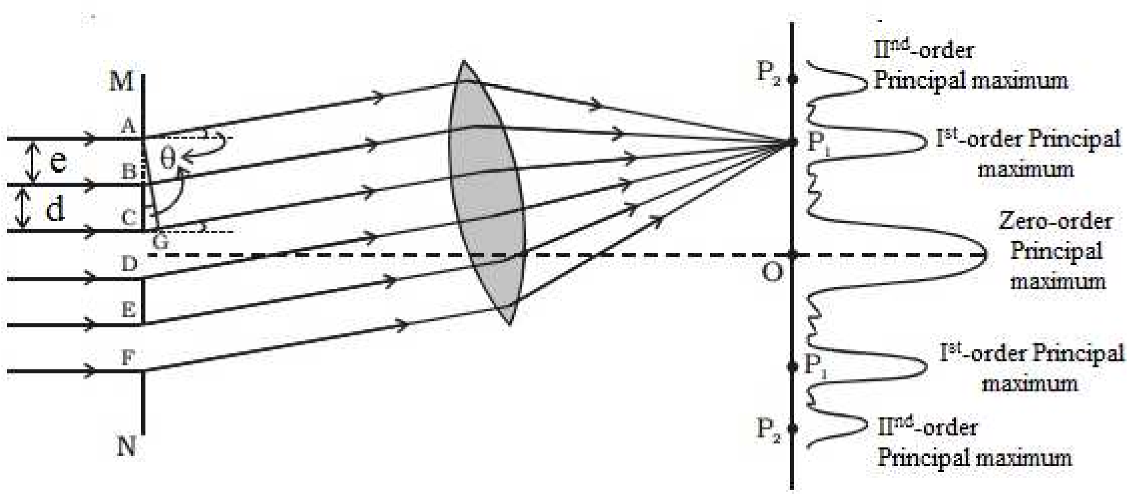


Fig. 3 Diffraction grating and its intensity pattern

From the above equation the wavelength λ of any light (He-Ne laser in our case) can be calculated as –

$$\lambda = \frac{(e+d)\sin\theta}{n} \text{ Å}$$

Where θ is angle of diffraction
n is the order of diffraction
$(e + d)$ is the grating element

Grating element (e + d) = (2.54)/N, where N is the number of ruling per inch on the grating surface

20.5 About Apparatus:

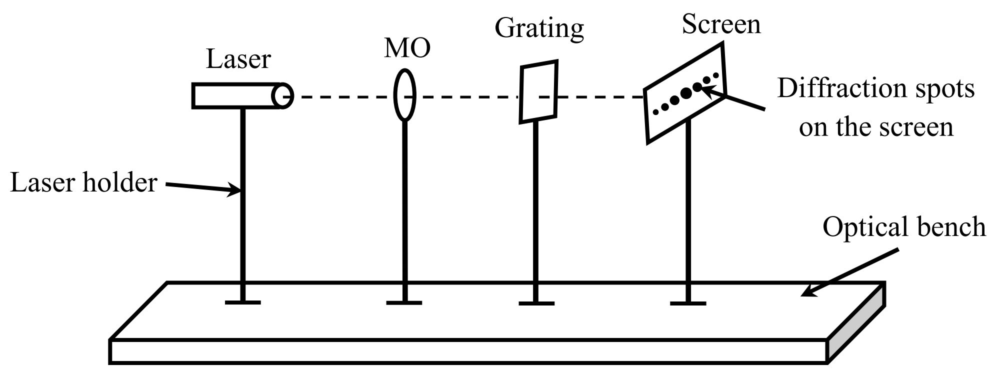


Fig. 4 Diffraction experiment setup

Different parts of the apparatus used to determine the wavelength of He-Ne laser is given below:

MO: Microscopic objective is a combination of good quality lenses that focus light with minimum aberration
Screen: Made up of millimeter graph sheet (Tracing paper could be used)
Laser: He-Ne laser of wavelength 6328 Å is used
Grating: Transmission grating (50 lines per inch or less) is used
Optical bench: is used as a base to hold them upward with the help of holders.

20.6 Procedure:

Fig. 4 shows the experimental set up for the experiment. All the apparatus, i.e., He-Ne laser, microscopic objective, diffraction grating and screen must be mounted in a line, so that the diffraction pattern (as spots) will be visible on the screen (graph sheet). The bright spot on the screen is the central maxima (zero-order) of the diffraction pattern. On both side of central maxima are other spots of diminishing intensity corresponding to different orders of diffraction.

20.7 Observations:

No. of rulings, N per inch on the grating = …………

If y be the distance between n[th] order maxima and the central maxima and x is the distance between screen and grating, then $\sin\theta = \frac{y}{x}$ radian $= \frac{180}{\pi} \times \frac{y}{x}$ degree. Using millimeter graph on screen will directly give the value of y in mm.

Observation table for determining sin θ corresponding to different y values

S. No.	Order of maxima (n)	y (in mm)	x (in mm)	sin θ = (180/π)×(y/x)
----	----	----	----	----
----	----	----		----
----	----	----		----
----	----	----		----
----	----	----		----

20.8 Calculations:

Grating element (e + d) = (2.54)/N, where N is the number of ruling per inch on the grating surface

= ---- per cm. = ---- per mm.

Wavelength of He-Ne laser is $\lambda = \frac{(e+d)\sin\theta}{n}$ Å

Find λ for different n values and corresponding sin θ and take mean.

20.9 Result:

The wavelength of He-Ne laser is = ……… Å,

Standard value: Standard value of wavelength of He-Ne laser is = 6328 Å

Percentage error $= \frac{\text{experimental value} \sim \text{standard value}}{\text{standard value}} \times 100$

= …….. %

20.10 Precautions and Source of Errors:

(i) Never look directly into the laser source

(ii) Choose proper grating for high order visible diffraction pattern.

(iii) Align all the apparatus on the optical bench so that the diffraction pattern can be visible on the screen.

20.11 Summary:

The wavelength of the He-Ne laser, which is four energy-level laser, can be calculated from diffracting the laser beam through diffraction grating. The experiment is setup accordingly.

20.12 Glossary:

Spontaneous emission: When an atom in an excited state E_2 falls to the ground state E_1 by spontaneously emitting a photon of frequency $\nu = (E_2 - E_1)/h$, where h is Planck's constant, the process is known as spontaneous emission. The emitted photon has energy $h\nu$ and can move in any random direction. In this processes the photons emitted from various atoms in the assembly have no phase relationship between them. Thus the radiations given out in spontaneous emission are incoherent.

Stimulated emission: When a photon of frequency exactly equal to $\nu = (E_2 - E_1)/h$, where h is Planck's constant, is incident on the atom in excited state E_2, then it induces (or stimulates) the atom to move to ground state E_1 by emitting a photon of the same frequency ν. This process is known as stimulated or induced emission. For every incident photon, we have two outgoing photons going in the same direction in this process. The emitted photons travel in the direction of the incident photon. Thus the emitted photons have the same frequency and are in phase with the incident photon. In this way we can achieve an amplified as well as an unidirectional coherent beam.

Population inversion: The situation in which the number of atoms in the higher energy state is greater than at in the lower energy state is called population inversion.

Diffraction: Bending of light through small (comparable to the wavelength of light) obstacle or aperture.

LASER: 'Light amplification by stimulated emission of radiation'

20.13 References:

(v) '*Fundamentals of Modern Physics*' by J.P. Agrawal and Amit Agarwal Pragati Prakashan.

(vi) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.

20.14 Viva-voce questions and Answers

Q. 1. What do you mean by spontaneous and stimulated emission?

Ans. See glossary

Q. 2. What are the important features of laser?

Ans. A laser is a device that amplifies light and produces a highly directional, high-intensity beam that most often has a very pure frequency or wavelength. It comes in sizes ranging from approximately one tenth the diameter of a human hair to the size of a very large building, in powers ranging from 10^{-9} to 10^{20} W and in wavelengths ranging from microwave to the soft X-ray spectral regions with corresponding frequencies from 10^{11} to 10^{17} Hz. Lasers have pulse energies as high as 10^{4} J and pulse durations as short as 6×10^{-15} s. They can easily drill holes in the most durable of materials and can weld detached retinas within the human eye.

Q. 3. What is meant by population inversion? How it can be achieved?

Ans. Under the conditions of thermal equilibrium given by the Boltzmann distribution, the number of atoms in the higher energy states is less than the number of atoms in the lower energy state. If by some means we could create a situation in which the number of atoms in the higher energy state is greater than at in the lower energy state is called population inversion. The process of achieving population inversion is called pumping. There are various types of pumping process but the most common is optical pumping (in Ruby laser), electrical discharge (in He-Ne laser) etc.

…………….O…………….

Experiment 21: To Measure Specific Charge (e/m) of an Electron by Helical Method

Structure:

21.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- How the direction of motion of an electron changes when it enters the magnetic field which is perpendicular to its direction of motion?
- What is meant by specific charge?
- What do you mean by cyclotron radius?

Also by performing the experimental part, you will be able to find out the value of specific charge (e/m) for an electron.

21.2 Introduction:

The charge to mass ratio is a physical quantity that is most widely used in the electrodynamics of charged particle, e.g. in electron optics and ion optics. It appears in the scientific fields of electron microscopy, cathode ray tube (CRT), accelerator physics, nuclear physics, Auger electron spectroscopy, cosmology and mass spectrometry. The importance of the charge to mass ratio, according to classical electrodynamics, is that two particles with the same charge to mass ratio move in the same path in a vacuum, when subjected to the same electric and magnetic fields.

When a charge particle moves through a magnetic field the Lorentz force acts on it. If the direction of the magnetic field is perpendicular to the direction of motion of the charged particle than the particle move in a circular path and the radius of curvature of the circular path depends upon the velocity, magnitude of magnetic field and charge to mass ratio.

Above can be used for the motion of an electron (charged particle) in cathode ray tube (CRT). The cathode ray tube is based on the facts that an electron beam is deflected by an electric and magnetic field and a bright spot is produced when electron beam strikes the fluorescent screen. With proper arrangements we can calculate the value of charge to mass ratio (e/m) using CRT.

21.3 Apparatus Used:

A cathode ray tube, a solenoid of proper dimension in the interior of which a cathode ray tube can be placed, a control which contains under it a power supply and controls (i) to operate the tube (ii) to operate the solenoid (iii) to provide variable a.c. voltages for deflecting plates, an ammeter (of dc 1A range), voltmeter (of 1.5 k-Volts range), one commutator.

21.4 Theory and Formula Used:

If an electron passes through a voltage V it accelerate to a velocity v, which is given by the equation – $\frac{1}{2}mv^2 = eV$, hence $v = \sqrt{\frac{2eV}{m}}$, where e and m are the electronic charge and mass respectively. (i)

Let us suppose such an electron moving in a direction is subjected to a cross magnetic field B, then a force (= Bev) acts on it in direction at right angles to both v and B. The electron describes a circular path in such a case and its motion is governed by the relation –

$$Bev = \frac{mv^2}{R} \text{ , (force is balanced by centrifugal force)} \qquad \text{(ii)}$$

where R (= mv/eB) is the radius of curvature of the circular path of the particle moving in the magnetic field. This is called ***gyro*** radius or ***cyclotron*** radius. Thus, larger the velocity of the particle (electron in this case) or larger it's mass, greater the radius. On the other hand, larger the charge (electron in this case) or B, smaller the radius.

As a result of cross forces the electrons follow a helical path. However, if a beam of electron moving in x-direction in a cathode ray tube (CRT) is subjected to a small deflecting ac voltage V_d say in Y-direction, then a line is traced on the fluorescent screen of the CRT. In case the time of flight of such electrons from the deflecting plates becomes equal to the time period of rotation imposed in accordance with relation (ii), the line turn into a focused point for a particular value of magnetic field B. This is the basis of magnetic focusing of electrons. Such a focusing takes place for time of flight being equal to integral multiple of time period of rotation.

On this basis the value of e/m occurring in relations (i) and (ii) is experimentally evaluated by using specially designed CRTs. The apparatus therefore consists of a CRT, a power supply to operate CRT and produce magnetic field by passing current through a multilayer long solenoid.

Solving relations (i) and (ii) under the specific condition of magnetic focusing, the value of specific charge, the ratio of the charge e to its mass m, is given by the following relation –

$$\frac{e}{m} = \frac{8\pi^2 V}{L^2 B_c^2} \text{ (in coulomb.kg}^{-1}\text{)} \qquad \text{(iii)}$$

Where L= Distance of fluorescent screen of the CRT from its deflecting plates to give a line of suitable span on screen (in meters).

V = the accelerating voltage to impart velocity v to the electrons in the beam (in volts).

B_c = Critical value of magnetic field which is required to focus the electronic beam on the screen (in Tesla).

In case of a long solenoid the value of magnetic field B in the central region is uniform and it is given by the following relation:

$$B = \mu_0 n I \qquad \text{(iv)}$$

Where $\mu_0 = 4\pi \times 10^{-7}$ T.m.A^{-1}, the magnetic permeability of free space.

n = the number of turn per unit length of solenoid (in m^{-1}).

I = Current flowing in solenoid (in amperes).

21.5 About Apparatus:

The apparatus for experiment consists of a power unit to run the CRT and a long multilayer solenoid to produce required B in accordance with relation (ii). The solenoid dimensions are suitable to hold the CRT as shown in the Fig. 1

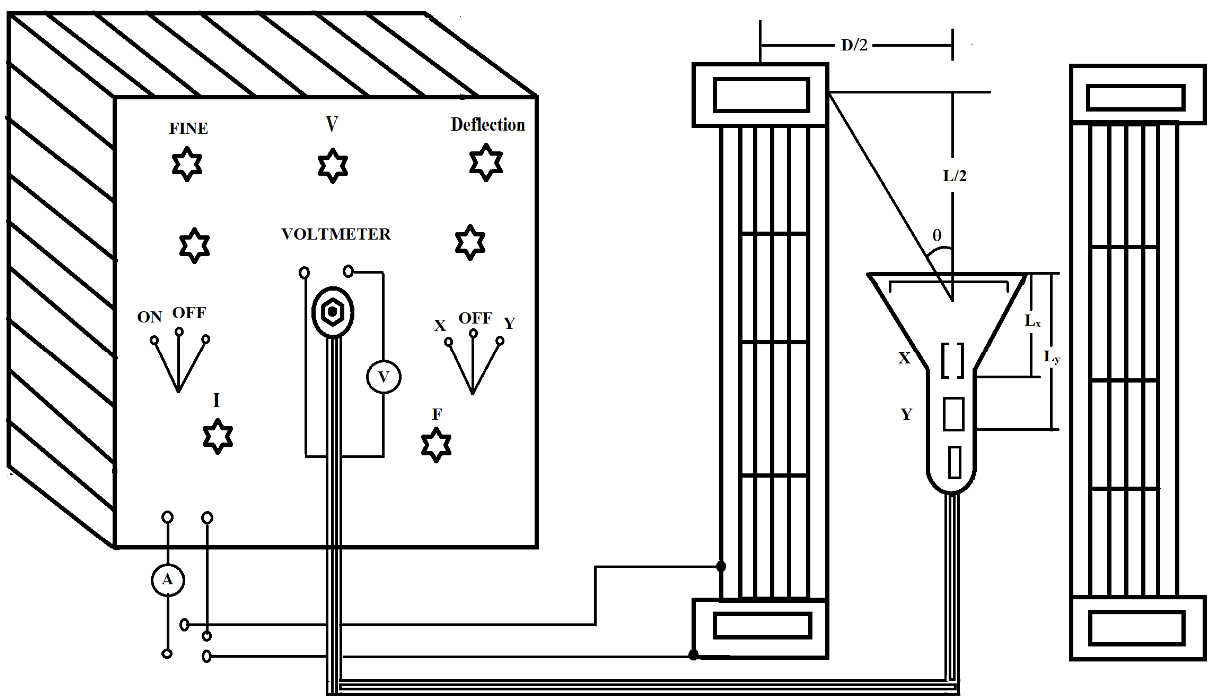


Fig. 1 Basic circuit for experiment (power supply to operate the CRT and the solenoid)

21.6 Procedure:

(i) Note down the value of constants of the solenoid and tube. In case of multilayer solenoid if the number of layers in the solenoid is say, N and the number of turns per meter per layer is n' then the value of n = n'N.
(ii) Set the axis of solenoid in east-west direction. Insert the cathode ray tube inside the solenoid and place it in middle of the solenoid. To avoid the stray magnetic field, power unit must be kept far away as possible.
(iii) Switch on the power unit. Keeping solenoid current I to zero, fix the accelerating voltage V to any desired value. At this stage a fine and clear spot must appear on the cathode ray tube.

(iv) Apply ac deflecting voltage to any one of the plates (either X-plate or Y-plate) and adjust its value to give a deflection of 15 to 20 mm.
Now apply the solenoid current and increase the current till the line is reduced to small focused point. Using commutator, reverse the solenoid current and readjust the control to a fine focused point. Take the average of these two values in amperes and it will be I_c. Using eq. (iv) calculate the value of B_c, i.e., $B_c = \mu_0 n I_c$.
(v) Using eq. (iii), calculate the value of e/m.
(vi) Repeat procedure of point (iv) above with different plates [if in point (iv) X-plates are used then this time Y-plates has to be used]. Keep the same deflection as in point (iv). Find the value of I_c.
(vii) Repeat the whole procedure from point (iii) to (v) with more other values of accelerating voltage (generally three value of accelerating voltage are sufficient). Spot on the tube must be refocus at each accelerating voltage.

21.7 Observations:

Distance between the edge of X-plate and the screen L_X = …………. meter.

Distance between the edge of Y-plate and the screen L_Y = …………. meter.

Number of layers in the solenoid N = ……………

Number of turns per meter per layer n' = ……………

Number of turn per unit length of solenoid n = n'N = …………..

S. No.	Using X-Plates					Using Y-Plates					Final value of e/m (A+B)/2
	Direction of current	**Accelerating voltage, V (volts)**	**Current, I_c (amp)**	**Value of e/m**	**Mean (A)**	**Direction of current**	**Accelerating voltage, V (volts)**	**Current, I_c (amp)**	**Value of e/m**	**Mean (B)**	
1	One direction	----	----	----	----	One direction	----	----	----	----	----

	Other direction		----	----		Other direction		----	----		
2	One direction	----	----	----	----	One direction	----	----	----	----	----
	Other direction		----	----		Other direction		----	----		
3	One direction	----	----	----	----	One direction	----	----	----	----	----
	Other direction		----	----		Other direction		----	----		

21.8 Calculations:

(i) With the help of X-Plate results –

$$\left(\frac{e}{m}\right)_X = \left(\frac{8\pi^2 V}{L_X B_c^2}\right) \text{ Coulomb/kg.}$$

(ii) With the help of Y-Plate results –

$$\left(\frac{e}{m}\right)_Y = \left(\frac{8\pi^2 V}{L_Y B_c^2}\right) \text{ Coulomb/kg.}$$

After taking means of both the values we will get the final value of e/m.

21.9 Result:

The value of e/m = ……….coulomb/kg.

Standard value : Standard value of e/m = **1.758×10^{11} Coulomb/kg**.

$$\text{Percentage error} = \frac{\text{experimental value} \sim \text{standard value}}{\text{standard value}} \times 100$$

$$= \ldots\ldots\ldots \%$$

21.10 Precautions and Source of Errors:

(i) Accelerating voltage is very high so it should apply very carefully.
(ii) Power unit must be kept far away as possible.
(iii) Before applying ac voltage a fine and clear spot must be appear on the cathode ray tube
(iv) After applying ac voltage, obtain a clear, well focused, sharp line on screen of cathode ray tube. It should be of moderate size.

21.11 Summary:

In the helical method a cathode ray tube is inserted in a solenoid and e/m determined from the condition for focusing deflected electrons to a spot on the screen. This has been modified by substituting alternating current in the solenoid and simultaneously supplying a voltage to the deflection plates proportional to the solenoid current. As a result, all electrons move in spirals of the same radius and the pattern observed is a portion of a circle (provided the beam has been properly centered). By adjusting the solenoid current until a full circle just appears, e/m may be deduced.

21.12 Glossary:

Lorentz force: **t**he force act on a charged particle when it moves through a magnetic field.
Cathode Ray Tube: a device which converts electrical signal into visible one.
Cyclotron radius: radius of curvature of the circular path of the charged particle moving in the magnetic field.
Critical magnetic field: Critical value of magnetic field which is required to focus the electronic beam on the screen.

21.13 References:

(vii) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.
(viii) '*Advanced Practical Physics Vol. I*', S.P. Singh, Pragati Prakashan.

21.14 Viva-voce questions and Answers

Q. 1. What is meant by specific charge (e/m) of an electron?
Ans. It is the ratio of charge to mass of an electron.

Q. 2. What is the standard value of e/m of an electron?

Ans. With e = 1.6 × 10^{-19} Coulomb and m = 9.1 × 10^{-31} kilogram, the value of e/m = 1.758 × 10^{11} Coulomb/Kilogram.

Q. 3. What is the significance of determining e/m?

Ans. From this experiment it proves that all cathode ray particles are electrons.

Q. 4. What are the different parts of cathode ray tube?

Ans. Cathode ray tube consists of an evacuated glass tube, a filament, an electron gun, a pair of vertical and horizontal deflecting plates and a fluorescent screen.

Q. 5. What will happen to an electron moving with velocity v in a direction enters in a magnetic field, which is perpendicular to its direction of motion.

Ans. Electron will experience a force of magnitude veB, where B is the magnetic field, v is the velocity and e is charge of electron. The direction of this force is always perpendicular to the direction of motion of electron so electron will move in circular path.

Q. 6. What do you mean by critical current?

Ans. The solenoid current at which the trace of line on CRT screen reduces into a focused point is called the critical current and corresponding magnetic field is called critical magnetic field.

…………….O…………….

Experiment 22: To determine the value of Planck's constant h by a photo cell

Structure:

22.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What is meant by photoelectric effect? How did Einstein explains this effect.
- What is meant by threshold frequency?
- What do you mean by work function?
- What is photo cell and how it works?

Also by performing the experimental part, you will be able to find out the value of Planck constant with the help of photo cell.

22.2 Introduction:

In this experiment our aim is to obtain the value of Planck's constant, which can be done with the help of Einstein theory of photoelectric emission. Einstein gave an equation which relates energy of the incident photon with the work function of the metal on which the photon falls and kinetic energy of the emitted electron. Using Einstein equation we can obtain the value of Planck's constant.

22.3 Apparatus Used:

Vacuum type photo emissive cell mounted in a wooden box provided with a wide slit, DC power supply, Optical bench with uprights, rheostat, voltmeter, a set of filter, key, galvanometer and connection wires (Fig. 1).

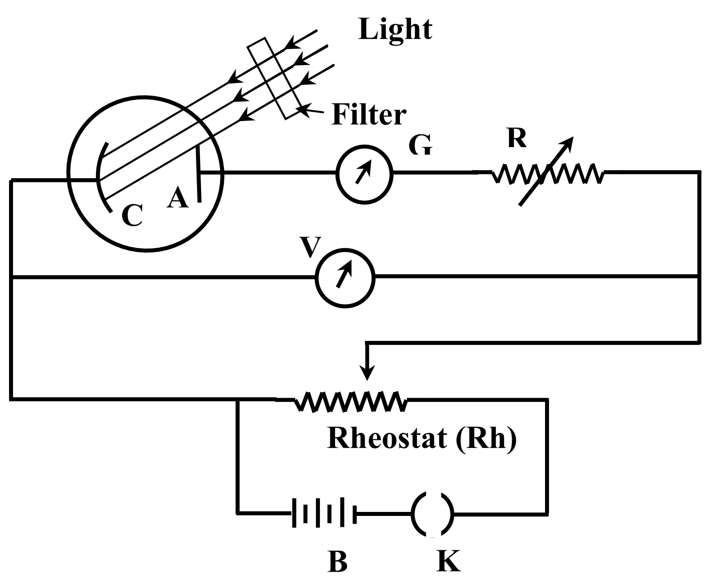


Fig. 1. Circuit diagram of photoelectric emission

22.4 Theory and Formula Used:

'The electrons are ejected out from the metallic surfaces by impact of light on them' the effect is known as ***photoelectric effect*** and the emitted photon are called ***photoelectrons***. The theoretical explanation of photoelectric effect was given by Einstein, in 1905. He based his arguments on Planck's idea of quantum theory, according to which the emission of radiation takes place in small packets of energy, called as ***quanta*** or ***photons***, rather than continuously. Einstein further assumed that light is not only emitted in quanta but also travels as quanta, i.e., when a photon collides with an electron of the metal, it transfer its energy to the electron which is an 'all or none' process, i.e., either the photon gives whole of its energy hν to the electron or no energy at all. When a photon of energy hν is incident on a metal surface, its energy is used up in two ways:

(i) A part of energy of the photon is used in ejecting out the electron from the binding forces of the nucleus. This energy used in doing work to eject out of electron from the atom is expressed as the ***work function*** of the photo-metal.

(ii) The remaining energy of the photon is used to impart kinetic energy to the same electron.

It may be noted that the energy of the photon is not divided, but the whole energy of a photon is used up by the same electron in ejecting it out from the parent atom and imparting it a velocity. If W be the work function of the photo-metal, m be the mass of the electron and v its velocity of ejection, then we have –

Energy of photon = Work function + Kinetic energy of electron

or $$h\upsilon = W + \frac{1}{2} m v^2 \qquad (1)$$

This is known as ***Einstein photoelectric*** equation. This equation can be put in slightly different form by making use of threshold frequency ν_0 (The minimum value of frequency of incident light below which the photoelectric emission stops completely, how so ever high the intensity of light may be). At threshold frequency (ν_0), the kinetic energy of emitted photoelectron is just zero, therefore, the work function (W) in equation (1) is equal to $h\nu_0$, and equation can be written

as - $$h\upsilon = h\upsilon_0 + \frac{1}{2} m v^2$$

or $$\frac{1}{2} m v^2 = h(\upsilon - \upsilon_0)$$

or $$\frac{1}{2} m v^2 = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_0}\right) \qquad (2)$$

This is Einstein's photoelectric equation.

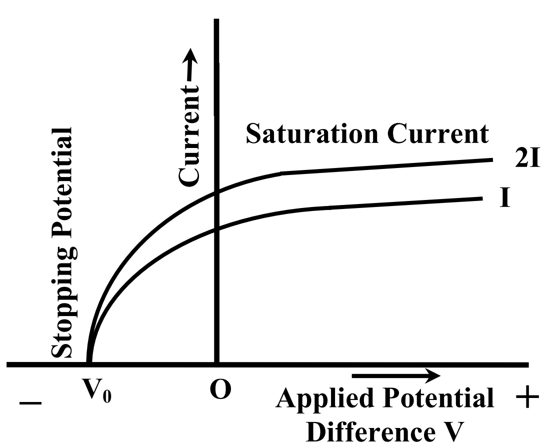


Fig. 2. A variation of photo-current with ± potential difference between the photo-metal C and A

Now the results of photoelectric effect shows that, keeping the intensity and frequency of radiation constant, if the potential difference between two electrodes is increased, the photo-current also increases and ultimately reaches a saturation value. The current does not increase beyond this on increasing the voltage V. It may be noted that a little current flows even when the anode A is made slightly negative. It happens because the emitted electrons have finite velocity and are able to overcome the force of small repulsion. Saturation is reached when all the emitted electrons have been attracted by the anode A. A variation in photo-current with ± potential difference between the photo-metal C and A is shown in Fig. 2. In figure, the photo-current just starts at V_0, a negative potential on photo-anode A. The potential is called stopping potential or cut off potential. It may be defined as the retarded potential for which the photoelectric current just becomes zero. It depends upon the frequency (or wavelength) of the incident light.

If m be the mass of the photo-electron emitted with velocity v then kinetic energy associated with it –

$$\text{K.E.} = \frac{1}{2}mv^2 \qquad (3)$$

The stopping potential V_0 just balance this kinetic energy. Therefore if e be the electronic charge, then in this state of balance, we have

K.E. = Electrostatic potential energy

or
$$\frac{1}{2}mv^2 = eV_0 \qquad (4)$$

Now suppose, V_1 is the stopping potential corresponding to wavelength λ_1 and V_2 is the stopping potential corresponding to wavelength λ_2 of the incident light, then from equation (2) and (4) we will get –

$$eV_1 = h\left(\frac{c}{\lambda_1} - \frac{c}{\lambda_0}\right) \qquad (5)$$

and
$$eV_2 = h\left(\frac{c}{\lambda_2} - \frac{c}{\lambda_0}\right) \qquad (6)$$

Subtracting eq. (5) from eq. (6) we will get –

$$e(V_2 - V_1) = hc\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)$$, and from this equation we will get the value of Planck's constant

$$h = \frac{e(V_2 - V_1)\lambda_1 \lambda_2}{c(\lambda_1 - \lambda_2)} \quad (7)$$

Where, V_1 = stopping potential corresponding to wavelength λ_1

V_2 = stopping potential corresponding to wavelength λ_2

e = electronic charge, c = velocity of light

22.5 About Apparatus:

Main part of this experiment is photo emissive cell; a simple form of this cell is shown in Fig. 3. It has two electrodes – a cathode C and an anode A enclosed in a highly evacuated quartz bulb. The cathode is a semi-cylindrical plate coated with a thin layer of an alkali metal as sodium, cesium etc. This layer is photosensitive and emits electrons when light of frequency higher than the threshold frequency is made to fall on it. These electrons are attracted towards anode A which is in the form of a straight wire as shown in fig. 3. A small potential difference of the order of 10 volts is applied between anode and cathode by means of a battery and a micrometer (μA) is connected in series with the battery.

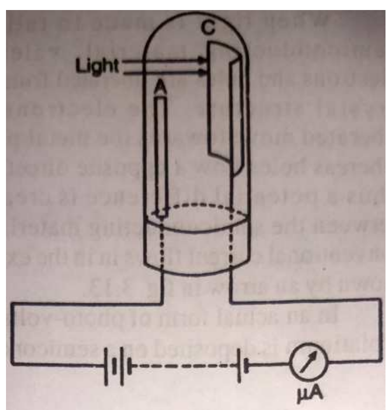


Fig. 3. Circuit of a photo cell

22.6 Procedure:

a. The electrical connections are made as shown in fig. 1.
b. The photocell is mounted at one end of the optical bench. At the same level and nearly 50-70 cm from the photocell, a light source is arranged. The light is allowed to fall on the cathode of photocell. Now a suitable filter (say yellow) of known wavelength is placed in the path of ray reaching the photocell.
c. A deflection is observed in galvanometer. If the deflection is out of the scale of galvanometer, then it is adjusted within the range of the galvanometer with the help of

rheostat R connected in series of galvanometer. This value on the galvanometer scale corresponds to zero anode potential as key K is open.

d. A small negative potential is applied to the anode by closing key K and adjusting the rheostat R_h. This voltage is recorded with the help of voltmeter. The corresponding galvanometer deflection is noted.
e. The negative anode voltage is gradually increased in small steps and each time corresponding deflection is noted till the galvanometer deflection reduces to zero.
f. The experiment is repeated after replacing the yellow filter in succession by two more filter e.g., green and blue.
g. Taking negative anode potentials on X-axis and corresponding deflections on Y-axis, graphs are plotted for different filters.

22.7 Observations:

S. No.	Negative anode potential (in volts)	Deflection in galvanometer (no. of division)		
		Yellow filter λ_1 = ….. Å	Green filter λ_2 = ….. Å	Blue filter λ_3 = ….. Å
1	….	….	….	….
2	….	….	….	….
3	….	….	….	….
4	….	….	….	….
5	….	….	….	….
.	….	….	….	….
.	….	….	….	….
.	….	….	….	….

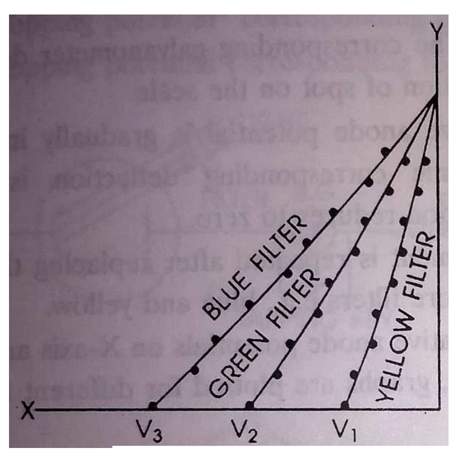
The graph between anode potential and galvanometer deflection is shown in Fig. 4.

From the graph the stopping potential are –

For yellow filter V_1 = …. Volts

For green filter V_2 = …. Volts

For blue filter V_3 = …. Volts



Galvanometer Deflection ⟶

⟵ Negative Anode Potential

22.8 Calculations:

Electronic charge $e = 1.6 \times 10^{-19}$ coulomb
Speed of light $c = 3 \times 10^{8}$ m/sec.
Wavelength of yellow filter $\lambda_1 = \ldots\ldots$ Å $= \ldots\ldots$ m
Wavelength of green filter $\lambda_2 = \ldots\ldots$ Å $= \ldots\ldots$ m
Wavelength of blue filter $\lambda_3 = \ldots\ldots$ Å $= \ldots\ldots$ m **Fig. 4.**

a. For yellow and green filters (from eq. 7) $h_1 = \dfrac{e(V_2 - V_1)\lambda_1 \lambda_2}{c(\lambda_1 - \lambda_2)}$ joule – sec
$= \ldots\ldots\ldots$ joule–sec.

b. For green and blue filters (from eq. 7) $h_2 = \dfrac{e(V_3 - V_2)\lambda_2 \lambda_3}{c(\lambda_2 - \lambda_3)}$ joule – sec
$= \ldots\ldots\ldots$ joule–sec.

c. For yellow and blue filters (from eq. 7) $h_3 = \dfrac{e(V_3 - V_1)\lambda_1 \lambda_3}{c(\lambda_1 - \lambda_3)}$ joule – sec
$= \ldots\ldots\ldots$ joule–sec.

Mean value of Planck's constant $= (h_1 + h_2 + h_3)/3 = \ldots\ldots\ldots$ joule–sec.

22.9 Result:

The value of Planck's constant (h) = ……… joule–sec.
Standard value: Standard value of Planck's constant (h) = 6.625×10^{34} joule–sec.

Percentage error $= \dfrac{\text{experimental value} \sim \text{standard value}}{\text{standard value}} \times 100$
$= \ldots\ldots$ %

22.10 Precautions and Source of Errors:

(i) To avoid any stray light to photocell, the experiment should be performed in a dark room.
(ii) The observation should be taken by changing anode voltage in small steps of volt.
(iii) The deflection in galvanometer should be adjusted at its maximum value corresponding to zero anode voltage.
(iv) Stopping potential should be read carefully.

22.11 Summary:

Einstein theory explains all the fundamental laws (see Q.2) of photoelectric emission. From the Einstein equation we can obtained the value of Planck's constant (explain in section 24.4).

22.12 Glossary:

Photo cell:	It is a glass bulb enclosing a photo metal as cathode and another electrode as anode. When light falls on cathode it emits electron.
Quanta:	Energy packets whose energy is integer multiple of hν.
Threshold frequency:	The minimum value of frequency of incident light below which the photoelectric emission stops completely.
Stopping potential:	The retarding potential for which, the photoelectric current becomes zero.
Work function:	The minimum amount of energy required to liberate electron from the bondage of its atom.

22.13 References:

(ix) '*Fundamentals of Modern Physics*' by J.P. Agrawal and Amit Agarwal, Pragati Prakashan.

(x) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.

22.14 Viva-voce questions and Answers

Q.1. What is photoelectric effect?

Ans. When a light of high frequency is incident on certain metals e.g., sodium, potassium, the electrons are emitted. This process is called photoelectric effect and electrons are called photo-electrons.

Q.2. What are the fundamental laws of photoelectric emission.

Ans. **The fundamental laws of photoelectric emission are as follows:**

(i) The rate of photo-emission is directly proportional to the intensity of the incident radiations.

(ii) The velocity and hence the kinetic energy of emitted photo-electrons is independent of intensity.

(xi) The kinetic energy of the emitted photo-electrons is directly proportional to the frequency of the incident radiations.

(xii) The photo-emission takes place only above a certain frequency known as threshold frequency. This is the characteristic frequency for the photo-metal used.

(xiii) There is no time lag between the incident of radiation and emission of photo-electrons.

Q.3. Explain the Einstein's photoelectric equation.

Ans. Energy of photon = Work function + kinetic energy of electron

or $h\nu = h\nu_0 + \frac{1}{2} m v^2$

where h is Planck's constant, ν is the frequency of incident photon, ν_0 is threshold frequency, m is mass of the electron and v is the velocity of electron.

Q.4. Is this method is most suitable to obtain the Planck's constant.

Ans. Vacuum photocells are not easily available now and reasonably strong source of monochromatic light is also difficult to maintain in an undergraduate laboratory (in our case we are using filters to get monochromatic light).

Note: Read glossary for more information

…………….O…………….

Experiment 23: To find out the value of energy band gap in semiconductor using a PN junction diode.

Structure:

23.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What is meant by reverse saturation current?
- What is meant by band gap in semiconductor material?
- Temperature dependence of reverse saturation current.

Also by performing the experimental part, you will be able to find out the value of energy band gap in a semiconductor using PN junction diode.

23.2 Introduction:

In this experiment our aim is to obtain the value of the energy band gap in a semiconductor using a PN junction diode. Band gap can be calculated from reverse saturation current, which depends upon the temperature of the junction diode.

23.3 Apparatus Used:

Power supply (DC- 3V fixed), micro-ammeter, electrically heated oven (100 ^{o}C for germanium based diode & 500 ^{o}C for Si based diode), thermometer, semiconductor diode.

23.4 Theory and Formula Used:

The electrical conduction in pure semiconductors is due to the thermally generated electron-hole pairs. The energy band structure of pure semiconductor is shown in Fig. 1. Most of the electrons reside in valence band, whose top level is shown as E_V. The conduction band, whose bottom level is E_C is almost vacant. The energy difference between E_C and E_V, i.e., E_C - E_V is called the band gap, E_g, (or forbidden gap) of the semiconductor. For conduction of electricity a certain amount of energy is to be given to the electron (thermal energy in this case), so that it goes from valence band to the conduction band. The energy so needed is the measure of the energy gap, E_g, between two bands.

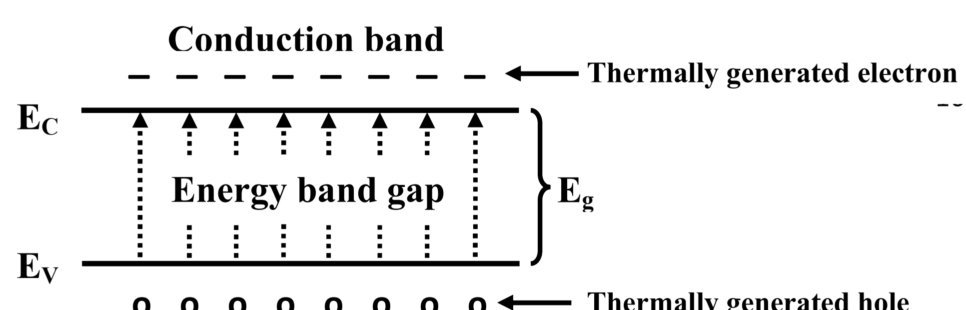


Fig.1. Energy bands in pure semiconductor and thermal origin of electron-hole pairs

When PN junction is reverse-biased (P terminal is connected to –ve terminal and N type is connected to +ve terminal of the DC power supply), the current flow is due to minority carriers whose concentration depends on the energy band gap and temperature of the junction. The reverse saturation current density is given by [Ref. 1]

$$J_s \sim \left[T^3 \exp\left(-\frac{E_g}{kT}\right)\right] T^{\gamma/2} = T^{(3+\gamma/2)} \exp\left(-\frac{E_g}{kT}\right) \quad (1)$$

Where k is Boltzmann constant (=1.38066×10^{-23} J/K), E_g is the energy band gap (in eV), T is the temperature of the junction (in Kelvin), γ is the constant.
The temperature dependence of the term $T^{(3+\gamma/2)}$ is not important compared with the exponential term in eq. (1). The slope of the plot J_s or I_s (saturation current) versus 1/T determines the energy gap E_g. So in terms of saturation current and taking only exponential term of eq. (1), the relation is expressed as –

$I_s \propto \exp\left[-\frac{E_g}{kT}\right]$, converting the value of k from J/K to eV/K and taking log to the base 10 of both side (1 eV = 1.60218×10^{-19} J), we will get –

$$\textbf{Log } I_s = \textbf{Constant} - 5.032E_g\,(10^3/T) \quad (2)$$

Now, if a graph in log I_s versus (10^3/T) is plotted it should come out to be a straight line. The slope of this line will be 5.032 E_g, giving the value of band gap for the semiconductor.

23.5 Procedure:

ii. Connect micrometer in the reverse biased PN junction circuitry according to Fig. 2. Put the diode in place on the board for heating and fix a thermometer to measure the temperature.

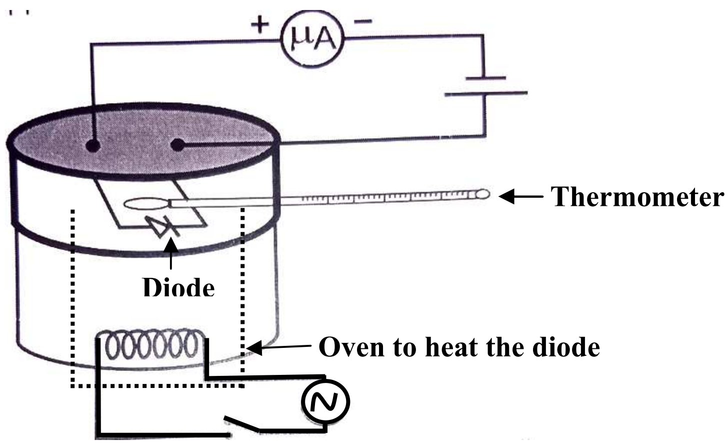


Fig.2. Temperature control unit, the reverse biased germanium diode and the electrical circuit to measure I at different temperatures T.

iii. Start heating by connecting oven's lead to mains and allow the oven temperature to increase upto 70 ^{o}C.

iv. As temperature reaches about 70^{o}C, switch off the oven. The temperature will raise further, say to about 75^{o}C and will become stable.

v. Now temperature will begin to fall. Take current in (μA) with the help of micrometer and temperature reading in steps of 4μA fall in current.

23.6 Observations:

S. No.	Current I_s (in μA)	Temperature (^{o}C)	Temperature T (in Kelvin)	$10^3/T$	Log I_s
1	-----	-----	-----	-----	-----
2	-----	-----	-----	-----	-----
3	-----	-----	-----	-----	-----
4	-----	-----	-----	-----	-----

23.7 Calculations:

Plot a graph between Log I_s and $10^3/T$ Fig. 3, and find the slope xy/yz.

Find $E_g = \frac{xy/yz}{5.032} = ...$ eV.

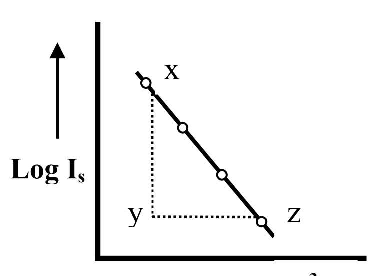


Fig. 3 Graph between Log I_s and $10^3/T$

23.8 Result:

The value of band gap for semiconductor (Ge) = …. eV

Standard value : Standard value of band gap for semiconductor (Ge) = .72 eV

Percentage error $= \dfrac{\text{experimental value} \sim \text{standard value}}{\text{standard value}} \times 100$

= …….. %

23.9 Precautions and Source of Errors:

(i) Maximum temperature should not exceed 80 ^{o}C.

(ii) If silicon diode is used, it requires an oven to provide variation upto about 500 ^{o}C.

(iii) Diode should be placed well inside the groove so that it is in good contact of the heat of the oven.

(iv) The response of mercury thermometer for decreasing temperature does not tally the response of diode current due to great difference between the thermal capacities of two in present case.

23.10 Summary:

Energy band diagram of semiconductor shows that in between conduction band and valence band there exist a forbidden gap and called energy band gap of the semiconductor. The value of this band gap in insulator is more than 3 eV and does not exist in conductors. PN junction diode when connected in reverse bias mode the current flow across the junction is due to the minority carriers and is called reverse saturation current. The concentration of these minority carriers depends upon the band gap and temperature of the junction. The relation between saturation current, energy band gap and temperature comes out to be a straight line. The slop of which gives the energy gap of the semiconductor.

23.11 Glossary:

Conduction band:	The unfilled energy levels into which electrons can be excited to become conductive electrons; a band that when partially occupied by mobile electrons, permits their net movement in a particular direction, producing the flow of electricity through the solid.
Valence band:	The energy band containing the valence (outer) electrons.
Band gap:	Energy gap between bottom of the conduction band and top of the valence band.
Saturation current:	Current flow across PN junction when connected in reverse bias mode.
Micro-ammeter:	An instrument used for measuring the electrical current flow (in micro-ampere) in a portion of a circuit.
Bias:	Voltage applied to the electrodes in an electrical device, considering polarity

23.12 References:

(xiv) '*Physics of Semiconductor Devices*' by S.M. Sze, John Wiley and Sons.
(xv) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.

23.13 Viva-voce questions and Answers

Q.1. What is a band gap or forbidden gap?

Ans. The energy gap between conduction and valence band is known as forbidden gap or energy band gap

Q.2. What is band gap in a good conductor?

Ans. In good conductors, i.e., metals, conduction band overlaps to valence band. So no band gap exist between conduction and valence band gap.

Q.3. What is meant by reverse saturation current in PN junction and on what factors does it depend?

Ans. The current which flows across the PN junction diode when it is in reverse bias mode, is called reverse saturation current. This current flows due to minority carriers whose concentration depends upon the band gap and temperature of the junction.

Experiment 24: Study of hydrogen spectra and Rydberg Constant

Structure:

24.1 Objectives:

After reading the text part of this exercise, you will be able to answer the followings:

- What are Bohr's assumptions?
- What is meant by a hydrogen spectrum?
- What is Rydberg's Constant?

Also by performing the experimental part, you will be able to find out the value of Rydberg constant with the help of diffraction grating and a hydrogen discharge tube.

24.2 Introduction:

In this experiment our aim is to obtain the value of Rydberg constant, which can be done with the help of Bohr's theory of hydrogen atom. From this theory, we will see that hydrogen spectrum produces different spectral series and Rydberg constant depends upon the wavelengths of these series. Different spectral lines fall in different regions of electromagnetic spectrum, e.g., Lyman series fall in ultra-violet region, Balmer series fall in visible region, etc. For finding the Rydberg constant, experimentally, Balmer series is very important because it is the only series which lies in visible range of electromagnetic spectrum.

24.3 Apparatus Used:

Spectrometer, diffraction grating, hydrogen discharge tube, transformer, spirit level and reading lens.

24.4 Theory and Formula Used:

In the year 1913, Niels Bohr developed a model of atomic structure which was in accurate quantitative agreement with the observed hydrogen and hydrogen like spectra. This model is based on following assumptions:

i. Bohr's first assumption was that the electron moves in circular orbits about the nucleus under the action of a Coulomb field force. The force of attraction between the electron of charge e and the nucleus of charge E will then be

$$F = \frac{eE}{a^2} = \frac{e^2 Z}{a^2} \tag{1}$$

Where a is the electron-nuclear distance, E = Ze, and Z is the atomic number; 1 for hydrogen, 2 for singly ionized helium, i.e., helium with one of its two electron removed, 3 for doubly ionized lithium, i.e., lithium with two of its three electrons removed, etc.

This force is equal to the centripetal force mv^2/a, where v is the velocity and m the mass of the electron. For equilibrium conditions, then,

$$\frac{e^2Z}{a^2} = \frac{mv^2}{a} \quad (2)$$

ii. Bohr's second assumption is that the electron revolves around the nucleus in various circular orbits for which the angular momentum of the electron is an integral multiple of $h/2\pi$, where h is the Planck's constant. Hence

$$mva = \frac{nh}{2\pi}, \text{where } n = 1, 2, 3 \text{ etc. gives the quantum number} \quad (3)$$

iii. The electron, in spite of its accelerated motion, does not radiate electromagnetic energy while moving in an allowed orbit. Thus its total energy remains stationary.

iv. When an electron jumps from lower energy state to a higher energy state it absorbs energy and when it jumps from a higher energy level to lower energy level it gives out electromagnetic radiation of a particular frequency

$$E_{n2} - E_{n1} = h\upsilon \quad (4)$$

Where E_{n2} is the energy of the n_2 energy level and E_{n1} is the energy of n_1 energy level and ν is the frequency of the electromagnetic radiation.

Substituting the value of v from eq. (3) in eq. (2), we get

$$e^2Z = mav^2 = ma\frac{n^2h^2}{4\pi^2m^2a^2} = \frac{n^2h^2}{4\pi^2ma}$$

$$\therefore \quad a = \frac{n^2h^2}{4\pi^2m\,Ze^2} \quad (5)$$

Putting the value of a from eq. (5) in eq. (3) we will get

$$v = \frac{2\pi\,Ze^2}{nh} \quad (6)$$

The application of the angular momentum quantization condition restricts the possible circular orbits to those of radii given by eq. (5). These radii are proportional to n^2.

Let us now calculate the total energy of an electron moving in one of the allowed orbits. Let us define the potential energy of the electron to be zero when the electron is infinitely distance from the nucleus. Then the potential energy V at a finite distance a, from the nucleus is equal to the work done in removing the electron from a to infinity against the electrostatic attraction ($-Ze^2/a^2$), and is given by -

$$v = \int_a^\infty -\frac{Ze^2}{a^2}\,da = -\frac{Ze^2}{a}$$

The kinetic energy of the electron is $K = \frac{1}{2}mv^2 = \frac{1}{2}\frac{Ze^2}{a}$ [from eq. (2)]

The total energy of the electron, E, is $E = K + V = \frac{1}{2}\frac{Ze^2}{a} - \frac{Ze^2}{a} = -\frac{1}{2}\frac{Ze^2}{a}$.

Substituting the value of a, from eq. (5), we get for the total energy of the electron in the n^{th} orbit, as

$$E_n = -\frac{1}{2}\frac{Ze^2}{n^2h^2 / 4\pi^2 mZe^2}$$

Or $$E_n = -\frac{2\pi^2 m Z^2 e^4}{n^2h^2}, \quad n = 1, 2, 3, \ldots \qquad (7)$$

For hydrogen atom Z = 1, and let E_{n1} and E_{n2} be the energy corresponding to n_1^{th} and n_2^{th} orbits respectively, then

$$E_{n1} = -\frac{2\pi^2 m e^4}{n_1^2 h^2} \quad \text{and} \quad E_{n2} = -\frac{2\pi^2 m e^4}{n_2^2 h^2}$$

Now from eq. (4), $$\upsilon = \frac{E_{n2} - E_{n1}}{h} = \frac{2\pi^2 m e^4}{h^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

And the wave numbers of the emitted lines are given by

$$\frac{\upsilon}{c} = \frac{1}{\lambda} = \frac{2\pi^2 m e^4}{ch^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Or $$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right),$$

$$\text{where } R_H = \frac{2\pi^2 m e^4}{ch^3} \; (\text{Rydberg's constant for hydrogen}) \qquad (8)$$

Spectral series of hydrogen atom:

a. **Lyman series:** When an electron jumps from an outer orbit to the first orbit, the spectral lines are in ***ultra violet region***, i.e., $n_1 = 1$ and $n_2 = 2, 3, 4, 5$ ……. etc.

b. **Balmer series:** When an electron jumps from an outer orbit to the second orbit, the spectral lines are in ***visible region***, i.e., $n_1 = 2$ and $n_2 = 3, 4, 5, 6$ ……. etc.

c. **Paschen series:** (***Infrared Region***) When $n_1 = 3$ and $n_2 = 4, 5, 6, 7$ ……. etc.

d. **Brackett series:** (***Far Infrared Region***)When $n_1 = 4$ and $n_2 = 5, 6, 7, 8$ ……. etc.

e. **Pfund series:** (***Far Infrared Region***)When $n_1 = 5$ and $n_2 = 6, 7, 8, 9$ ……. etc.

The theoretical explanation of Balmer series was a great success for Bohr's theory (Fig. 1). The success was particularly impressive because the Lyman, Brackett, Pfund series had not been discovered at the time of theory was developed by Bohr. The existence of these series was predicted by the theory, and the series were observed experimentally in 1916, 1922 and 1924 respectively at the predicted positions.

For finding the Rydberg constant, experimentally, Balmer series is very important because it is the only series which lies in visible range of electromagnetic spectrum. In Balmer series, the wavelength corresponding to the quantum number n_2 is given by

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n_2^{\,2}}\right), \text{ where } n_2 = 3, 4, 5.......$$

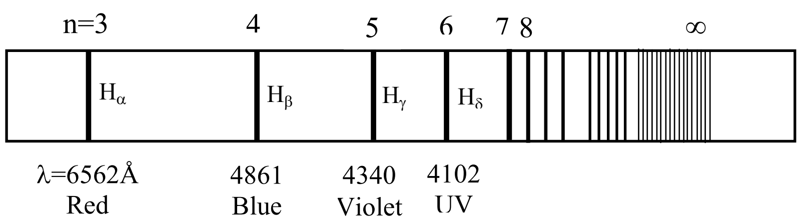


Fig.1 Balmer Series of hydrogen

Thus the value of the Rydberg constant can be easily be calculated by experimentally determining the wavelength of the above prominent lines for the corresponding value of n_2.

24.5 About Apparatus:

Main part of this experiment is spectrometer, which is a basic instrument for measuring wavelengths and refractive indices. Generally transmission grating is used to determine the wavelengths of spectral lines (colours) and a material in prism shape is used to determine the refractive index. Spectrometer consists of the following parts:

i. ***Collimator:*** This part is used to obtain a parallel beam of light. It consists of two hollow cylindrical metallic tubes, one being longer than the other. The longer tube carries an achromatic lens at one end and the smaller tube on the other end. The smaller tube is provided with a slit at the outer end and can be moved in or out the longer tube with the help of rack and pinion arrangement. Also the width of the slit can be adjusted with the help of a screw with spring, attached to it. When the slit comes exactly into the focal plane of the lens, the beam of light coming out of the lens will be parallel beam.

ii. ***Prism table and the circular scale:*** It is a circular metallic platform to carry either a grating or a prism. It is mounted at the centre of the instrument and is provided with three spring screws, which forms vertices of equilateral triangle. These crews are used to level the platform. The prism table can be move up and down and clamped by a side screw. The upper surface of the platform has concentric circles and parallel lines to the line joining two of the spring screws, for keeping the grating or prism in suitable position. The platform is mounted on the axis of the spectrometer and can be rotated about it. The rotation of the table can be measured with the help of two verniers fitted 180^o apart to a large concentric disc. The verniers slide on the circular scale which is attached to a telescope. It is provided with a clamping screw and a tangential screw.

iii. ***Telescope:*** It is meant to receive the parallel transmitted or reflected beam from the grating or prism. It consists of similar cylindrical tubes as in case of collimator carrying achromatic objective lens at one end and Ramsdon eyepiece on the other side end. The eyepiece tube can be move in or out with the help of rack and pinion arrangement. Two crosswire are focused on the focus of the eyepiece. Telescope can be rotated about a vertical axis and the amount of rotation angle can be measured on the circular scale. It is provided with the clamping and tangential screws. The clamping screw when tightened locks the telescope in position while the tangential screw helps to move the telescope very slowly. Tangential screw works only when the clamping screw is tightened. The whole assembly is mounted on a heavy metallic base having three leveling screws.

24.6 Procedure:

vi. Spectrometer must be adjusted as follows:

a. Prism table should be leveled with the help of three screws supporting the prism table, which are just below the prism table. A spirit level is placed along a line joining the screw and the two screws are rotated till the air bubble shifted to the middle. Now place the spirit level along the line perpendicular to the previous line and adjust the third screw such that again the air bubble shifted to the middle. Make sure that in the previous position air bubbled in the spirit level is still in the middle.
b. Focusing of the eyepiece of the telescope on the crosswire
c. The telescope axis and the collimator axis must intersect the principal vertical axis of rotation of the telescope.

vii. Grating should be normal to the axis of collimator and is done as follows (See Fig. 2):

a. Collimator and telescope are arranged in a line and the image of the slit is focused on the vertical crosswire. The reading is noted on both the verniers.
b. The telescope is now rotated through 90^o.
c. Mount the grating on the prism table so that the reflected image is seen on the vertical cross wire. Take the reading of the verniers.
d. Turn the prism table from this position through 45^o or 135^o. In this position the grating is normal to the incident beam.

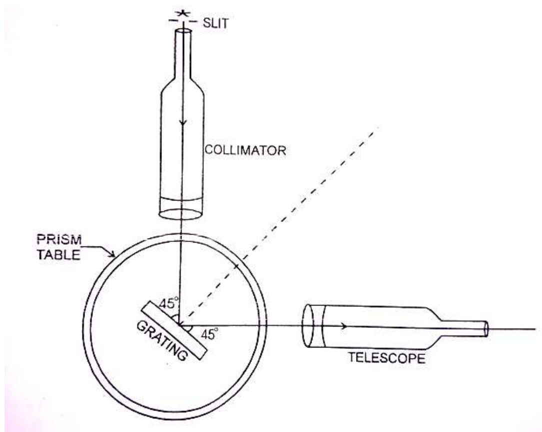


Fig. 2. Adjustment of grating and collimator

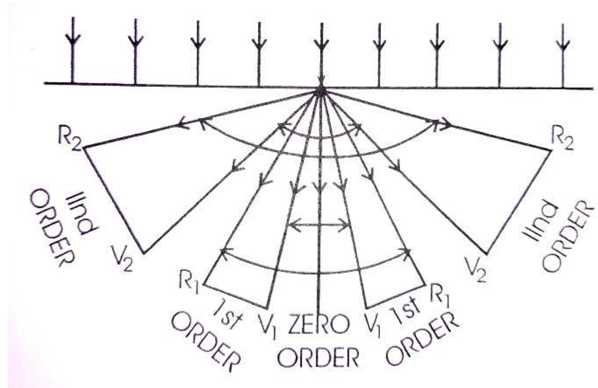


Fig.3 Spectrum obtained in a grating

viii. Angle of diffraction can be obtained as follows (See Fig. 3):

a. Rotate the telescope to the left of the direct image and adjust the different spectral lines (violet, green and red) of Ist order on the vertical crosswire. Note down the readings on both the verniers.

b. Rotate the telescope further to obtained the IInd order spectrum and again adjust the spectral lines on the vertical crosswire and note the readings on both the verniers.

c. Now rotate the telescope to the right of direct image and repeat the above procedure for Ist as well as for IInd order.

d. Find out the difference of the same kind of verniers for the same spectral lines in the Ist order and in the IInd order. The angle is the twice the angle of diffraction for that particular colour. Half of it will be the angle of diffraction.

e. Find out the angle of diffraction for other colours in for Ist and IInd order.

ix. Least count of the spectrometer is determined as follows:

It is to be noted that the spectrometer measures angles. The circular table is divided and graduated into 360^o. Each degree is further subdivided into two parts. Thus the smallest main scale division is equal to 0.5^o. Let us suppose the vernier has 30 equal divisions (it may be 60 in other spectrometers) and a portion of the circular main scale and vernier scale is shown in Fig. 4. For this model the calculation is as follows-

$$\text{Least count of spectrometer (LC)} = \frac{\text{Value of one division on main scale (in degree)}}{\text{Total division on Vernier scale}}$$

$$= 0.5^o/30 = 1/60^o = 1' \text{ (One minute)}$$

Main scale reading (MSR) = 110^o; Vernier coincidence (VSR) = 15

Therefore total reading = MSR + (VSR × LC)

= $110^o + (15 \times 1')$

= $110^o\ 15'$

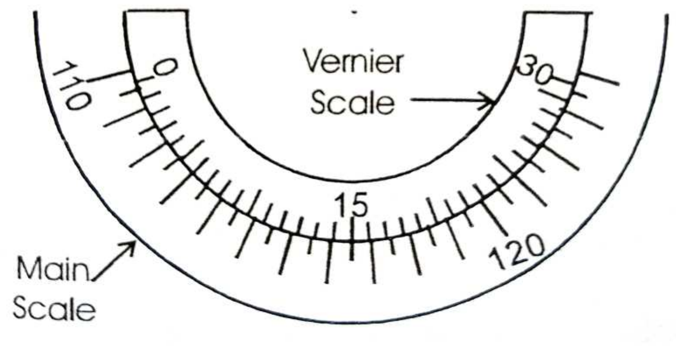


Fig. 4. Main and Vernier scale of spectrometer

24.7 Observations:

No. of rulings, N per inch on the grating = ………….

Least count of the spectrometer = ………..

Reading of telescope for direct image = ………….

Reading of telescope after rotating it through 90^o = …………..

Reading of circular scale when reflected image is obtained on the crosswire = ………..

Reading after rotating the prism table through 45^o or 135^o = ……………

Determination of angles of diffraction:

Order of spectrum	Colour of light	Vernier reading	Reading of telescope (for left side spectrum)			Reading of telescope (for right side spectrum)			$2\phi = x-y$	Mean ϕ (degree)
			M.S. reading	V.S. reading	Total (x) (degree)	M.S. reading	V.S. reading	Total (y) (degree)		
I	Violet	V_1	----	----	----	----	----	----	----	----
		V_2	----	----	----	----	----	----	----	
	Green	V_1	----	----	----	----	----	----	----	----

		V_2	----	----	----	----	----	----	----	
	Red	V_1	----	----	----	----	----	----	----	----
		V_2	----	----	----	----	----	----	----	
II	Violet	V_1	----	----	----	----	----	----	----	----
		V_2	----	----	----	----	----	----	----	
	Green	V_1	----	----	----	----	----	----	----	----
		V_2	----	----	----	----	----	----	----	
	Red	V_1	----	----	----	----	----	----	----	----
		V_2	----	----	----	----	----	----	----	

24.8 Calculations:

Condition for maxima in grating is given by: $(e + d) \sin \phi = n\lambda$, where n is an order of spectrum (e + d) is called grating element, ϕ is the angle of diffraction and λ is wavelength of the corresponding colour.

Grating element (e + d) = (2.54)/N, where N is the number of ruling per inch on the grating surface

= ---- per cm.

Wavelength of H_γ line (Violet Colour):

For first order (n = 1) $\lambda_\gamma = (e + d) \sin \phi =$ .... Å

For second order (n = 2) $\lambda_\gamma = \dfrac{(e+d)\sin\phi}{2}$ = …….. Å

So, the mean wavelength λ_γ for H_γ line = …….. Å

Similarly the value of wavelength for H_β line (Blue Colour) and H_α line (Red Colour) can be calculated.

Now, for H_γ line $\dfrac{1}{\lambda_\gamma} = R_H\left(\dfrac{1}{2^2} - \dfrac{1}{5^2}\right)$,

From this, Rydberg constant $(R_H) = \dfrac{1}{\lambda_\gamma} \times \dfrac{100}{21} =$ ....c m^{-1}

For H_β line $\dfrac{1}{\lambda_\beta} = R_H\left(\dfrac{1}{2^2} - \dfrac{1}{4^2}\right)$,

From this, Rydberg constant $(R_H) = \dfrac{1}{\lambda_\beta} \times \dfrac{4}{3} =$ ....c m^{-1}

Now, for H_α line $\frac{1}{\lambda_\alpha} = R_H\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$,

From this, Rydberg constant $\left(R_H\right) = \frac{1}{\lambda_\alpha} \times \frac{36}{5} = ...\text{c m}^{-1}$

So mean value of R_H = …….. cm^{-1}.

Theoretically from eq. (8), taking the known values of m, e, c and h upto six significant figures, we obtain the value of Rydberg constant is equal to **109678 cm^{-1}**.

24.9 Result:

The value of Rydberg constant (R_H) = ………cm^{-1},

Standard value : Standard value of Rydberg constant (R_H) = **109678 cm^{-1}**.

$$\text{Percentage error} = \frac{\text{experimental value} \sim \text{standard value}}{\text{standard value}} \times 100$$

= …….. %

24.10 Precautions and Source of Errors:

- (i) Prism table of the spectrometer should be properly leveled with the help of spirit level.
- (ii) Spectrometer should be adjusted before performing the experiment.
- (iii) Grating should be cleaned with smooth and dry cloth and should not be touch by fingers.
- (iv) The discharge lamp is placed close to the slit in order to increase the intensity of spectral lines
- (v) Grating should be set normal to the incident light.
- (vi) Reading should be taken with both Vernier scales.
- (vii) During taking observations, telescope and grating should be kept fixed.

24.11 Summary:

The Bohr model explains the atomic spectrum of hydrogen as well as various other atoms and ions. The spectrum of hydrogen can be expressed simply in terms of the Rydberg constant. The Rydberg constant represents the limiting value of the highest wave number (the inverse wavelength) of any photon that can be emitted from the hydrogen atom, or, alternatively, the wave number of the lowest-energy photon capable of ionizing the hydrogen atom from its ground state. Using visible spectral lines of hydrogen atom (Balmer Series), Rydberg constant can be obtained.

24.12 Glossary:

Bohr's Theory: A model of atomic structure which was in accurate quantitative agreement with the observed hydrogen and hydrogen like spectra.

Rydberg Constant: A wave number characteristic of the wave spectrum of each element.

Quantization: Is a process of constraining an input from a continuous or otherwise large set of values (such as the real numbers) to a discrete set (such as the integers).

Spectral Line: A line in a spectrum due to the absorption or emission of light at a discrete frequency.

24.13 References:

(xvi) '*Introduction to Atomic Spectra*' by H.E. White, McGraw-Hill Book Company.
(xvii) '*Atomic & Molecular Spectra*' by Raj Kumar, Kedar Nath Ram Nath .
(xviii) '*Practical Physics*' by S.L. Gupta and V. Kumar, Pragati Prakashan.

24.14 Viva-voce questions and Answers

Q.1. What do you mean by spectrum?

Ans. The sequence of the lines/colours emitted by an element is known as spectrum (emmision) of that element. Also The sequnec of the lines/colours absorbed by the element is known as the spectrum (absorption).

Q.2. What is meant by Bohr theory?

Ans. See the theoretical part of this experiment.

Q.3. Describe the nature of hydrogen spectra.

Ans. The hydrogen spectrum consists of Lyman series, Balmer series, Paschen series, Brackett series and Pfund series. The Balmer series lies in the visible region of electromagnetic spectrum. It consists of four prominent lines, as H_α, H_β, H_γ and H_δ.

Q.4. How will find the value of Rydberg constant from hydrogen spectrum.

Ans. We know that -

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n_2{}^2}\right), \text{ where } n_2 = 3, 4, 5 ....$$

Where R_H is Rydberg constant. The wavelength of a line corresponding n_2 is determined by using grating.

…………….O…………….