Hall Effect Setup

Nvis 6101

Learning Material

Ver 1.2

An ISO 9001: 2008 company

Designed & Manufactured in India by :

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Nvis 6101 Hall Effect Setup

Introduction

The Hall Effect Setup Nvis 6101 is a very useful system for the laboratory. It is used for the study and measurement of Hall Effect.

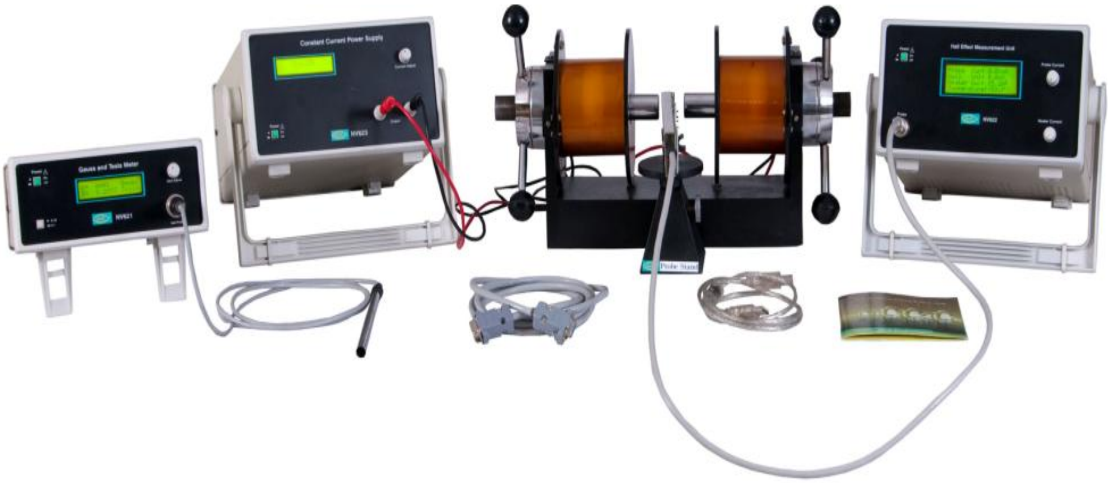
The Hall Effect is an important observation in its material science. If an electric current flows through a conductor in a magnetic field, it exerts a transverse force on the moving charge carriers, which tends to push them to one side of the conductor. It will balance this magnetic influence, producing a measurable voltage between two sides of the conductor, this voltage is Hall Voltage.

This system is provided with Gauss and Tesla meter with a sensor for measurement of magnetic field Measurement unit With LCD Display and PC interface for measuring hall voltage, probe current, heater current, Temperature, Hall Effect probe for the study of Hall Effect, constant current power supply with LCD display and electromagnet to produce magnetic field.

By this we can calculate carrier density, mobility of charge carrier, hall coefficient etc. We can study the effect of temperature in semiconductor, relation between magnetic field and hall voltage.

Setup consists of the following:

- Gauss and Tesla Meter Nvis 621 (InAs probe)
- Measurement Unit Nvis 622
- Constant current power supply Nvis 623
- Electromagnet
- Hall probe with Oven and Thermocouple



Features

- A complete set for the study of Hall Effect in semiconductor
- A Hall Effect probe is provided with p type germanium crystal with oven
- Measurement unit with LCD and PC interface. To measure hall voltage and probe current
- Provided with In As sensor for measuring magnetic field
- Constant current source provided with LCD display.
- Gauss and Tesla meter for measuring magnetic field with LCD display and PC interface facility
- Provided with an Electromagnet
- Provided with the power supply unit for an electromagnet

Technical Specifications

1 Gauss and Tesla meter Nvis 621

Microcontroller Based LCD Display for Measurement of Magnetic Field in Gauss and Tesla, with PC Interface facility.

Sensor : InAs for better sensitivity

Range : 0 – 20 KG

Special feature : Indicate the direction of the magnetic field

Mains : 230V AC ± 10 %, 50Hz

2 Measurement unit Nvis 622

Probe Current : 20 mA (max.)

Heater Current : 0-700 mA

Temperature : 0-55^{0}C

Mains : 230VAC ± 10%, 50Hz

a) Hall probe :

Crystal : p-type lightly doped

Resistivity : Mention on the Hall probe
Thickness : Mention on the Hall probe

b) Temperature Sensor : Temperature is measured with PT-100

3 Constant Current Power Supply Nvis 623

Current range : 0 to 3.5A

Output Voltage : 20V

Display : LCD 16 x 2

Mains : 230V AC ± 10%, 50Hz

4 Electromagnet

Poles : 25 mm diameter

Coils : 2 Nos.

Resistance : 5 Ohms (approximately)

Input Current : 3.5A at 20V

Weight : 16 Kg

Safety Instructions

Read the following safety instructions carefully before operating the instrument. To avoid any personal injury or damage to the instrument or any product connected to the instrument.

Do not operate the instrument if suspect any damage to it.

The instrument should be serviced by qualified personnel only.

For your safety:

Use proper Mains cord : Use only the mains cord designed for this instrument. Ensure that the mains cord is suitable for your country.

Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock, the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.

Use in proper Atmosphere : Please refer to operating conditions given in the manual.

1. **Do not operate in wet / damp conditions.**
2. **Do not operate in an explosive atmosphere.**
3. **Keep the product dust free, clean and dry.**

Theory

The Hall Effect is one of the rich sources of information about the conduction properties of semiconductors. The mobility and carrier concentration can be obtained from the Hall constant in conjunction with the resistivity; this cannot be done with the resistivity alone. The mobility is pertinent to the understanding of transistors since such things as high-frequency cut-off and the intrinsic current gain of the transistor are related to the property of germanium. The Hall Effect and associated thermo magnetic and galvano magnetic effects are discussed. The elimination of the effect of associated phenomena from the Hall measurement can be achieved in several ways.

What is a semiconductor?

The magic word semiconductor is composed of two words-Semi and Conductor. Semi means not completely while conductor mean something, which can conduct electricity. Everybody is familiar with "Electricity". It is present everywhere; it runs many appliances in your home and outside the home like TV, Bulb, Freeze, and Microwave Oven etc. In simple terms, the current must past through wires so that the electricity can reach all these appliances.

So a conductor is nothing but a material having ability to conduct this electricity. Semiconductors conduct electricity to some extent, less than the conductors, how much do you think? Well, it depends on the type of material or its mixture and size. A semiconductor is a material that has intermediate conductivity between a conductor and an insulator. It means that it has unique physical properties somewhere in between a conductor like aluminum and an insulator like glass. In a process called doping, small amounts of impurities are added to pure semiconductors causing large changes in the conductivity of the material. Examples include silicon, the basic material used in the integrated circuit, and germanium, the semiconductor used for the first transistors. A semiconductor is a substance, usually a solid chemical element or compound that can conduct electricity under some conditions but not others, making it a good medium for the control of electrical current.

Importance of Semiconductor

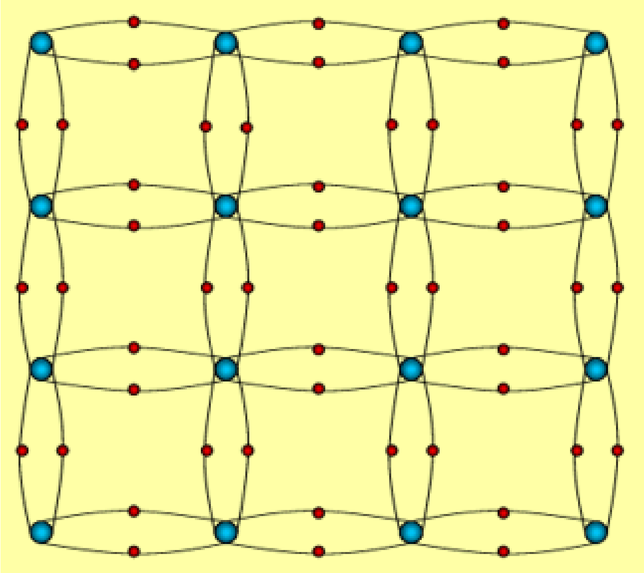
To understand the importance of semiconductors let's first understand the difference between electricity and electronics. Both are concerned with generating, transferring, and utilizing electrical energy. The chief difference is that electricity is concerned with using that electrical energy in power applications for heat, light, and motors while electronics is concerned with power control and communications applications such as electronic thermostats, electric motor speed control and radio. Engineering importance of semiconductors results from the fact that they can be conductors as well as insulators. Semiconductors are especially important because varying conditions like temperature and impurity content can easily alter their conductivity. The combination of different semiconductor types together generates devices with special electrical properties, which allow control of electrical signals.

Semiconductors are employed in the manufacture of electronic devices and integrated circuits. Imagine life without electronic devices. There would be no radios, no TV's, no computers, no video games, and poor medical diagnostic equipment.

Types of Semiconductor

Semiconductors are mainly classified into two categories: Intrinsic and Extrinsic. An intrinsic semiconductor material is chemically very pure and possesses poor conductivity. It has equal numbers of negative carriers (electrons) and positive carriers (holes). Where as an extrinsic semiconductor is an improved intrinsic semiconductor with a small amount of impurities added by a process, known as doping, which alters the electrical properties of the semiconductor and improves its conductivity. Introducing impurities into the semiconductor materials (doping process) can control their conductivity. Doping process produces two groups of semiconductors: the negative charge conductor (n-type) and the positive charge conductor (p-type). Semiconductors are available as either elements or compounds. Silicon and Germanium are the most common elemental semiconductors. Compound Semiconductors include InSb, InAs, GaP, GaSb, GaAs, SiC, and GaN. Si and Ge both have a crystalline structure called the diamond lattice. That is, each atom has its four nearest neighbors at the corners of a regular tetrahedron with the atom itself being at the center. In addition to the pure element semiconductors, many alloys and compounds are semiconductors. The advantage of compound semiconductor is that they provide the device engineer with a wide range of energy gaps and motilities, so that materials are available with properties that meet specific requirements. Some of these semiconductors are therefore called wide band gap semiconductors

Intrinsic Semiconductor



How do Semiconductor works

Most of the semiconductor devices and chips are created with silicon. The commonly heard expressions like "Silicon Valley" and the "Silicon Economy" come from this fact. In the periodic table, you will find that silicon sits next to aluminum, below carbon and above germanium. Carbon, silicon and germanium have a unique property in their electron structure -- each has four electrons in its outer orbital. This allows them to form nice crystals. The four electrons form perfect covalent bonds with four neighboring atoms, creating a lattice. In carbon, we know the crystalline form as diamond. In silicon, the crystalline form is a silvery, metallic-looking substance.

Metals tend to be good conductors of electricity because they usually have "free electrons" that can move easily between atoms, and electricity involves the flow of electrons. While silicon crystals look metallic, they are not, in fact, metals. All of the outer electrons in a silicon crystal are involved in perfect covalent bonds, so they can't move around. A pure silicon crystal is nearly an insulator -- very little electricity will flow through it. You can change the behavior of silicon and turn it into a conductor by doping it. In doping, you mix a small amount of an impurity into the silicon crystal. A minute amount of either N-type or P-type doping turns a silicon crystal from a good insulator into a viable (but not great) conductor -- hence the name "semiconductor."

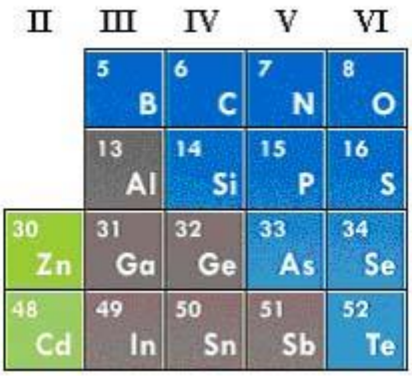
However electrons are not the only players in the "conduction game"! Another particle plays a major role in conduction in semiconductors. What is this particle? That is also what happens when an electron in a semiconductor jumps from the valence band to the conduction band. It is called a hole. Some electrons and holes play an important role in electrical conduction in semiconductors:

- These electrons are the ones that jumped in the conduction band
- These holes are the ones that are created in the valence band

Electrons have a negative charge. Holes have a positive charge. Electrons and holes are not static: they can move. Holes move more slowly than electrons. When electrons move in one direction, holes move in the opposite direction. This is like cars parked along astreet. If one car moves to an empty slot, the empty slot moves the other way. The cars move to the right, the empty slot to the left. A solitary electron in the presence of a solitary hole will recombine. Only electrons and holes which are free, and hence have not recombined, play a role in electrical conduction.

How are they made?

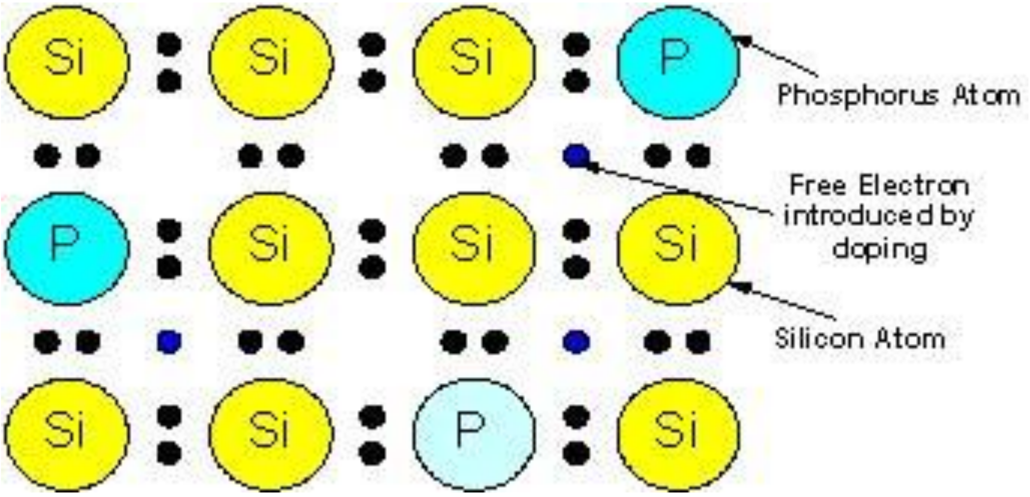
All the elements used to make semiconductors appear in Column IV of the Periodic Table or are a combination of elements in columns at equal distance of Column IV on each side



For example, two elemental semiconductor materials are silicon and germanium from Column IV. Another common compound is gallium arsenide (GaAs), Ga from Column III and As from Column V. The elements for zinc oxide (ZnO) are each two columns away from Column IV, Zn in Column II and O in Column VI.

All of these chemical bonds yield an average of four valence electrons per atom. These valence electrons are shared between all the atoms in the silicon crystal.

Semiconductors are important because of their electrical properties. Some semiconductors are probably the purest materials on earth. Any trace of unintended impurity atoms can have a drastic effect on those properties. When being manufactured, purity must be very carefully controlled. Intentionally added impurities are called do pants. Do pants are added in a controlled environment and it is known beforehand how many impurity atoms will be added and what the effect will be.



Properties of Semiconductor

Semiconductors have many useful properties that insulators and conductors do not possess. These properties are based on the fact that an electron can jump from the valence band to the conduction band and vice versa.

Temperature can give this little extra energy to an electron and make it jump to the conduction band thus creating a hole in the valence band. Light can also give this energy boost and create what we call an electron-hole pair: a free electron and a free hole: this phenomenon is called absorption. Photoconductivity is the increase of current in a semiconductor due to the absorption of photons. Light has a dual nature: it behaves as a wave and as a particle. The particle associated with light is called a photon. Photons can have different energies.

When light illuminates a semiconductor:

The photons with the right energy are absorbed by the material · the electrons from the valence band have enough energy to jump to the conduction band · the conductivity increases due to the higher number of electrons in the conduction band.

Electroluminescence is the conversion of electrical energy into light. Let's consider electrons in the conduction band. These electrons are in an excited state: they have gained some energy to jump to the conduction band.

Such electrons eventually fall back into the valence band in a lower energy state:

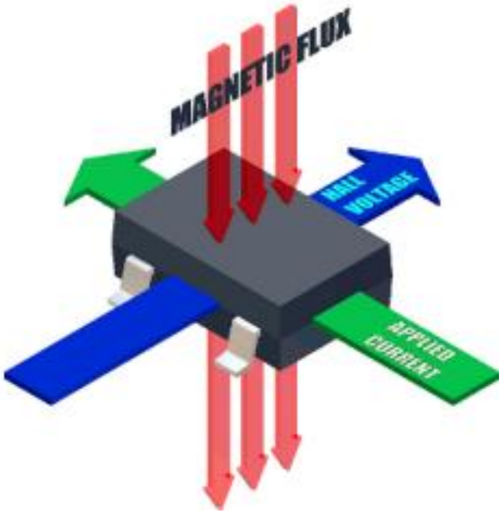
They release the extra energy that they have this energy is emitted as a photon Photons emitted by electroluminescence come out in random directions: this type of light is called incoherent light. For instance light from a light bulb is incoherent.

Stimulated emission is a little bit like electroluminescence except that it is not a spontaneous process: the excited electron is forced into jumping back to the valence band and emitting a photon.

Hall Effect

The Hall Effect comes about due to the nature of the current flow in a conductor. Current consists of the movement of many small charge-carrying "particles" (typically, but not always, electrons). These charges experience a force, called the Lorentz Force, when a magnetic field is present that is not parallel to their motion. When such a magnetic field is absent, the charges follow an approximately straight, 'line of sight' path. However, when a perpendicular magnetic field is applied, their path is curved so that moving charges accumulate on one face of the material. This leaves equal and opposite charges exposed on the other face, where there is a dearth of mobile charges. The result is an asymmetric distribution of charge density across the hall element that is perpendicular to both the 'line of sight' path and the applied magnetic field. The separation of charge establishes an electric field that opposes the migration of further charge, so a steady electrical potential builds up for as long as the current is flowing.

Nvis 6101 Hall Effect Setup



In the Hall Effect, magnetic flux perpendicular to the flow of

An electrical current results in a measurable voltage

Hall Effect in Semiconductors

The simple formula for the Hall coefficient given above becomes more complex in semiconductors where the carriers are generally both electrons and holes which may be present in different concentrations and have different mobility. For moderate magnetic fields the Hall coefficient is

$$R_H = \frac{n\mu_e^2 - p\mu_h^2}{e(n\mu_e + p\mu_h)^2}$$

Where n is the electron concentration, p the hole concentration, μ_e the electron mobility, μ_h the hole mobility and e the electronic charge. For large applied fields the simpler expression analogous to that for a single carrier type holds.

$$R_H = \frac{1}{(n-p)e}$$

If an electric current flows through a conductor in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor. This is most evident in a thin flat conductor as illustrated. A buildup of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall Effect after E. H. Hall who discovered it in 1879.

Note that the direction of the current I in the diagram is that of conventional current, so that the motion of electrons is in the opposite direction. That further confuses all the "right-hand rule" manipulations you have to go through to get the direction of the forces.

Hall Effect

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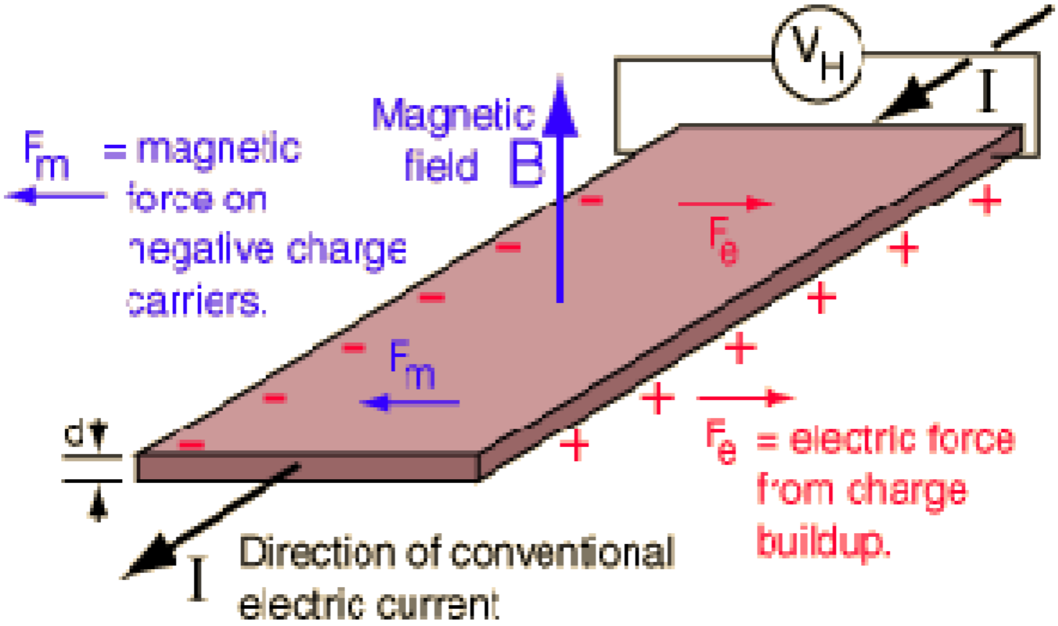


The Hall voltage is given by

$$V_H = \frac{IB}{(ned)}$$

n = density of mobile charges

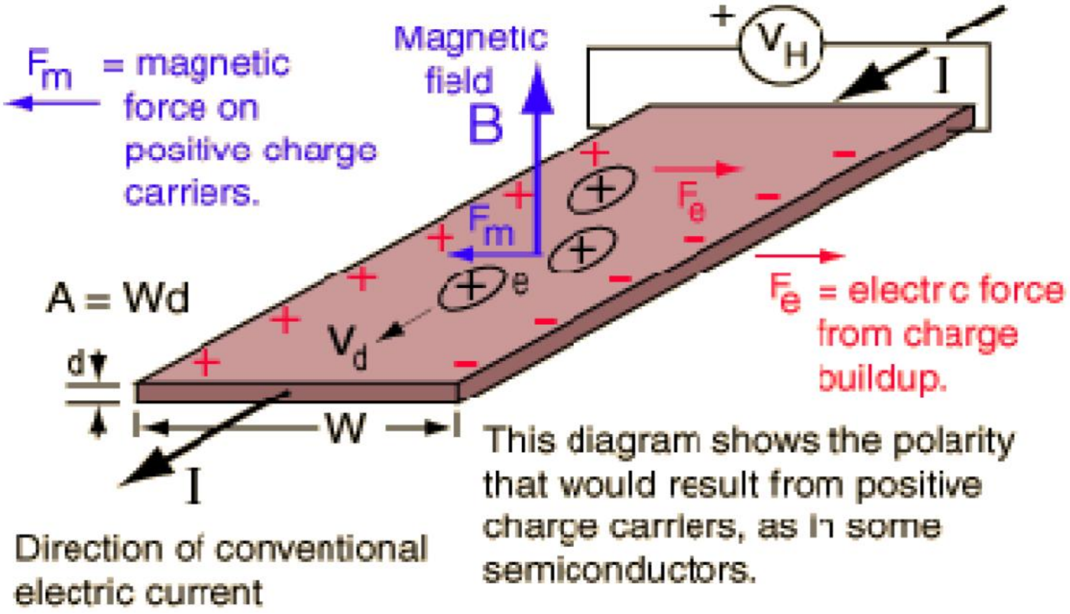
e = electron charge

The Hall Effect can be used to measure magnetic fields with a Hall probe

Hall Voltage for Positive Charge Carriers

The transverse voltage (Hall Effect) measured in a Hall probe has its origin in the magnetic force on a moving charge carrier.

The magnetic force is $Fm = eVdB$ Where V_d is the drift velocity of the charge.



The current expressed in terms of the drift velocity is

$$I = neAv_d$$

Where n is the density of charge carriers. Then

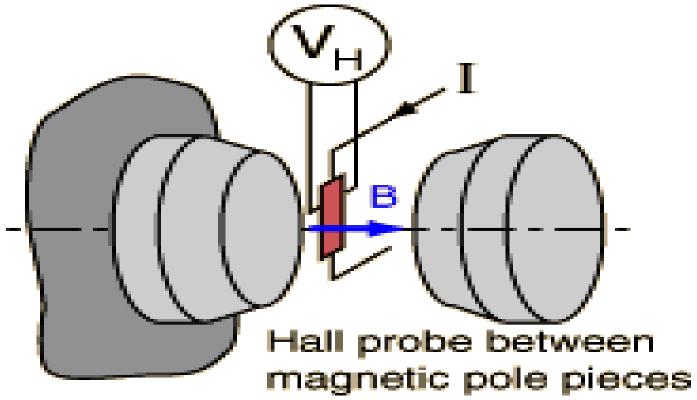
$$F_m=F_e\frac{VH_e}{W}$$

One very important feature of the Hall Effect is that it differentiates between positive charges moving in one direction and negative charges moving in the opposite. The Hall Effect offered the first real proof that electric currents in metals are carried by moving electrons, not by protons. The Hall Effect also showed that in some substances (especially semiconductors), it is more appropriate to think of the current as positive "holes" moving rather than negative electrons.

Hall Probe

The measurement of large magnetic fields on the order of a Tesla is often done by making use of the Hall Effect. A thin film Hall probe is placed in the magnetic field and the transverse voltage (on the order of microvolt) is measured.

Nvis 6101 Hall Effect Setup

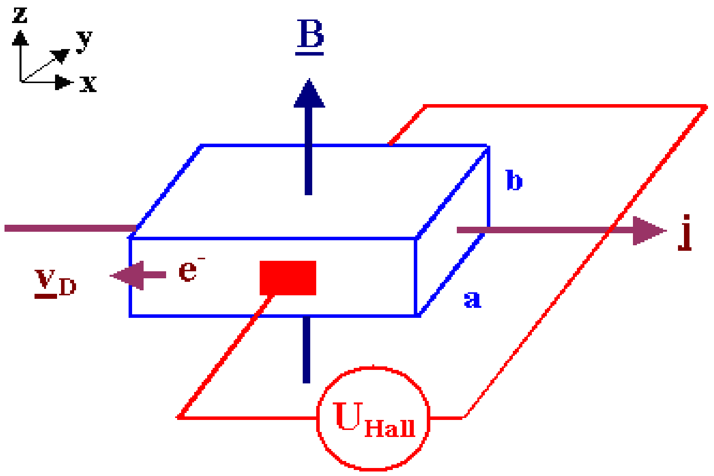


The polarity of the Hall voltage for a copper probe shows that electrons are the charge carriers.

Sometimes a thin copper film of thickness d on the order of 100 micrometers is used for a hall probe This subchapter introduces two important topics: The Hall effect as an important observation in materials science and at the same time another irrefutable proof that classical physics just can’t hack it when it comes to electrons in crystals. The Hall Effect describes what happens to current flowing through a conducting material – a metal, a semiconductor – if it is exposed to a magnetic field *B*.

We will look at this in classical terms; again we will encounter a fundamental problem the standard geometry for doing an experiment in its most simple form is as follows

A magnetic field *B* is employed perpendicular to the current direction j, as a consequence a potential difference (i.e. a voltage) develops at right angles to both vectors



In other words: A Hall voltage U_{Hall} will be measured perpendicular to $B$and j.

There may be almost as many means of sensing position and level as there are applications requiring these functions. Inductive, capacitive, mechanical, magneto-resistive, Hall Effect, and optical, to name just a few, are all viable sensing options and the list continues to expand. Yet for a designer, there always remain the same critical elements that need to be addressed and that inevitably mate the requirements of the application to the appropriate sensing technology. Critical requirements, such as: cost, distance of travel (effective operating air gap), resolution, accuracy, and often times cost again, all need to be determined to effectively and efficiently select the proper sensing technology. Of course, constructing answers for each of these elements is not always a straightforward task. Here, though, the flexibility of Hall-effect sensing technology is most advantage-either digital or analog output. The former option is optimal for sensing discrete positions, while the latter affords the user a relatively infinite number of positions for greater resolution. Some examples of applications requiring discrete position or level sensing are: automotive shift selectors, seat belt buckle switches, seat position sensors, cellular flip phones, and brushless dc motor commutation, windshield wiper fluid reservoirs, and gas tanks, to name just a few. Due to its high reliability, Hall-effect technology is used to replace reed switches and mechanical switches in these applications.

Most Hall-effect switches have output structures that are open drain and provide low resistance, thus simplifying the interface to most microprocessors and other digital electronics (threshold comparators, multiplexers, basic TTL gates, and so forth). Typical of open-drain outputs, once switched “on,” the output voltage of the Hall-effect device transitions from high to low. This being said, there is an abundance of variations for Hall-effect sensors in order to service to the plethora of position and level sensing applications, each one with its own nuances. These variations include features such as: micro-power consumption (A3211,-12, -13, and -14), magnetic pole-independent sensing (A3425), user-programmable options (A3250, and -51 and A1182, -83, -84,-85, and -86), two-wire current sourced output devices (A1142,-43, -44, -45, -46, -47, and -48 and A1182, -83, -84, -85, and -86) magnetic bias for sensing ferrous targets (ATS6*xx*), and inverted outputs (A3211). These cannot all be adequately discussed in one sitting, and for the purpose of this article, the focus will be on standard devices: their operation and application uses.

Gauss and Tesla meter Nvis 621

Gauss and Tesla meter is used to measure the magnetic field. It operates on the principal of Hall Effect. When a semiconductor carrying current place in a magnetic field direction of current and magnetic field should be perpendicular to each other an electromagnetic force develops which perpendicular to both field. This e.m.f. is small in magnitude .this voltage is amplified by a high stability amplifier circuit so that a milivoltmeter connected at the output of the amplifier can be calibrated directly in magnetic field.

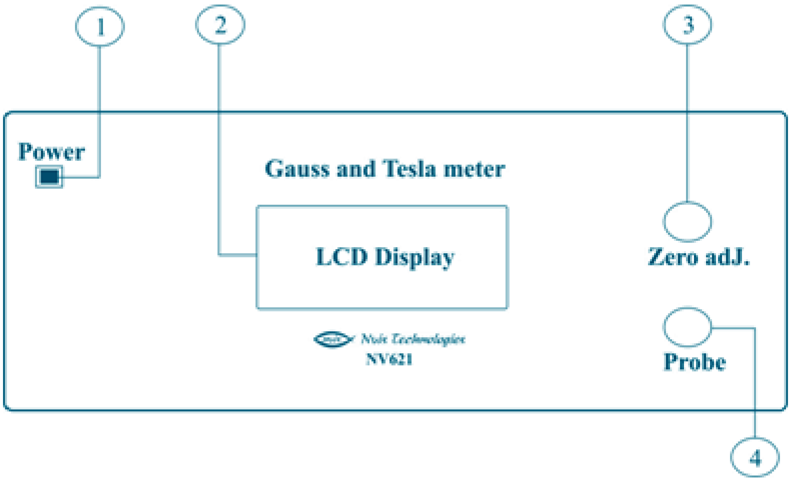
Sensor : InAs for better sensitivity

Range : 0 – 20 KG

Special feature : Indicate the direction of the magnetic field

Mains : 230V AC ± 10 %, 50Hz

Panel Control:



Front Panel Control:

1 **Power:** It is power on/off switch.

2. **LCD Display:** For monitoring magnetic field in Gauss and Tesla.

3 **Zero Adjust:** With the help of this potentiometer we can calibrate the meter for zero position

4. **Hall Probe:** It is input socket for connecting the probe.

Rear Panel:

1. **PC Interface:** we can connect a RS232 cable for connecting the meter with PC

Nvis 6101 Hall Effect Setup

Precautions:

Take care the InAs probe is very delicate cover it after use.

Measurement Unit Nvis 622

Microcontroller Based LCD Display for Measurement of Hall Voltage, Probe current, Heater current and Temperature With PC Interface facility.

Specifications

PC Interface : PC Interface facility with user friendly software

Crystal : P- type Ge Semiconductor

Hall Voltage : 0-200mV (100microvolt Min)

Probe Current : 0 – 20mA

Heater Current : 0 – 700mA

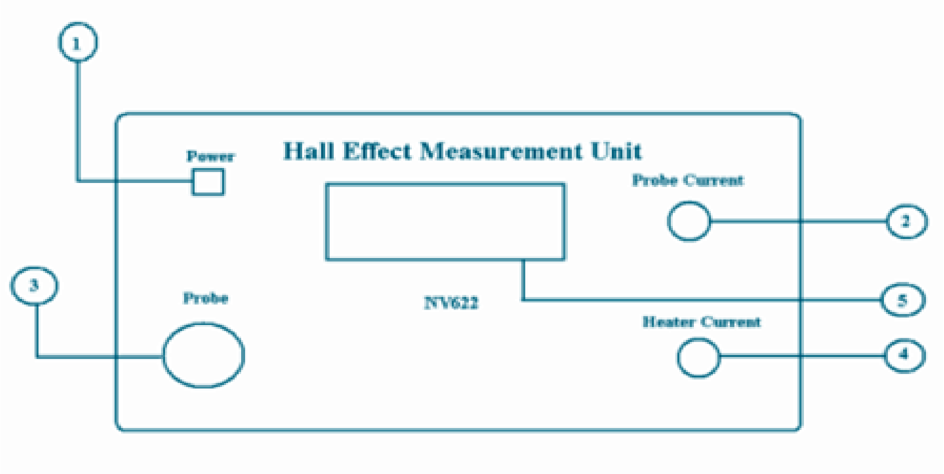
Temperature : 0-55^{0}C

Line Regulation : 0.1% for 0 to full load

Load Regulation : 0.03% for 0 to full load

Mains : 220V AC ± 10% /50Hz

Panel Control:



1 **Power:** Push button switches for supplying the power to the instrument.

2 **Probe Current:** with the help of this potentiometer we can vary and increase current in crystal

3 **Probe:** This is the input socket for connecting the Hall Effect probe.

4 **Heater Current:** By this potentiometer we can increase the heater current.

5 **LCD Display:** It displays Probe current, Hall Voltage Heater current temp.

Constant Current Power Supply Nvis 623

Specifications

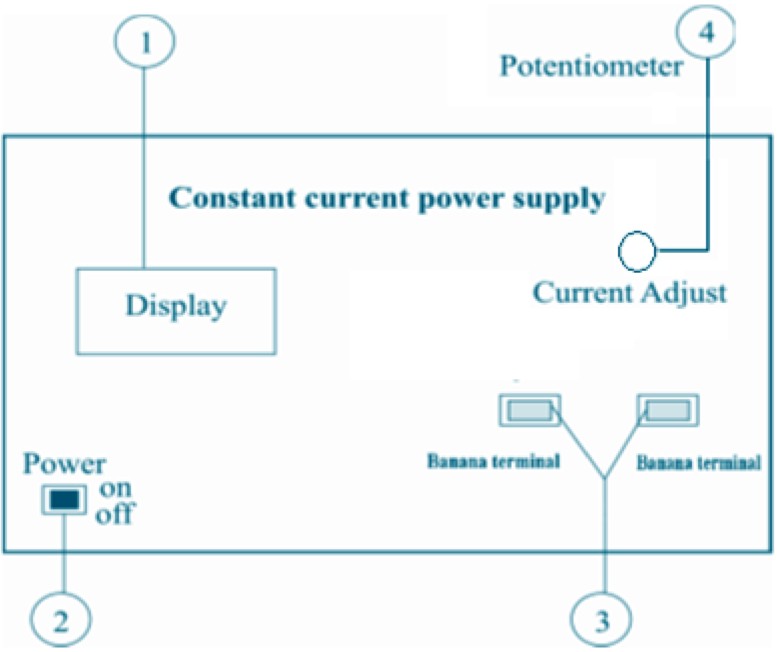
Display : LCD 16×2

Current : 0 to 3.5A

Voltage : 20V

Mains : 220V AC ± 10% /50Hz

High stability and regulation



Panel control

1 **LCD Display:** It shows the output current.

2. **Power:** It is power on/off switch.

3. **Output:** For connecting the electromagnet.

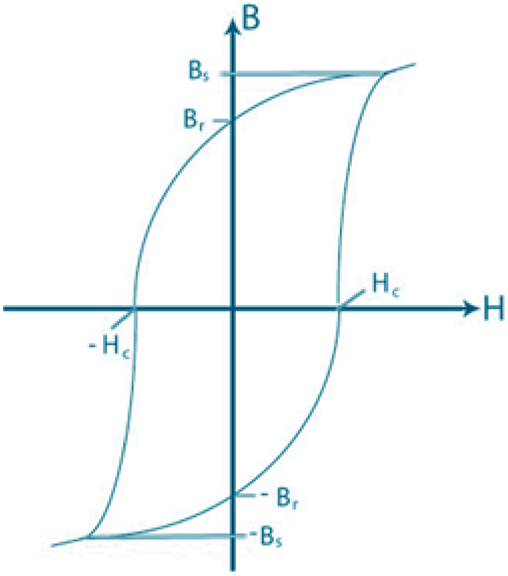
4. **Current Adjust:** By this we can adjust the current.

Precautions

Always increase or decrease the current gradually & switch on or off the Power supply at the zero current position.

Hysteresis in Electromagnet and How to reduce it

When current is passed through coil a temporary magnet is formed in the poles of the electromagnet. The material of the poles has some magnetic hysteresis. So a residual magnetic field or remnants magnetization, B_r is generated even when no current is passed in the coil. Please refer to the figure below.



The field required to reduce the magnetisation of the sample to zero is called the coercive field H_c. In the case of Electromagnet this field is applied by changing the direction of the current in the coil.

Method for reducing the remnant magnetization:

1. Make the air gap between the poles of the electromagnet equal to 20 mm.
2. Connect the electromagnet to the constant current power supply polarity wise and check the magnetic field in air gap with the help of Gauss and Tesla meter.

3. Increase the current in the coil so that maximum field is generated between the air gaps.
4. Now reduce the current in coil to zero and disconnect electromagnet.
5. Again check the magnetic field between the air gaps. There would be some magnetic field shown due to Hysteresis Effect. (Say 150 Gauss).
6. Now to reduce it, connect the electromagnet to the constant current supply in reverse polarity (red cable in black terminal and black cable in red terminal).
7. Increase the current slowly and simultaneously check the value of magnetic field in Gauss and Tesla meter. When current is increased the magnetic field is reduced to zero and when more current is supplied magnetic field value will become negative. The current should be increased such that a slightly more negative value equal to positive value is achieved (in our case -150 to -200 Gauss).
8. Switch off the constant current supply and remove the connection of electromagnet. Then check the value of magnetic field in the gap. Now it should be very close to zero.

Experiment 1

Objective: To measures the magnetic field of Electromagnet using Gauss & Tesla meter and InAs probe

Items Required

1 Electromagnet

2 Gauss and Tesla meter Nvis 621

3. PC Interface S/W (Nvis 621)

4. Hall Probe (InAs)

5. Constant Current Power supply Nvis 623

Procedure

1. Take Gauss & Tesla meter from the set of Hall Effect Setup .
2. Connect InAs probe and switch on the Gauss & Tesla meter.
3. Connect RS-232 cable between PC and Gauss & Tesla meter.
4. Adjust zero reading on display by Zero Adjust potentiometer and keep range selector switch at X1 position.
5. Now take Constant Current Power Supply & set the current ADJUST potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
6. Switch on the power supply & set some low value of current (Nvis 623).
7. Keep Hall probe (InAs) between electromagnet such that the flat face (Inner part of shielded probe) of the probe is kept perpendicular to the direction of magnetic field. Note the strength of magnetic field. (Keep distance between poles approximately 32mm)
8. Increase the current from the Constant Current Power Supply and note the value of corresponding magnetic field. If magnetic field is greater than 2k Gauss then meter will indicate the over range. For its measurement keep the selector switch at X10 position and note the value of magnetic field.
9. Now multiply the display reading by 10 to get the magnetic field strength in both Gauss & Tesla.

Record your readings in following table.

Sr. No.	Current (A)	Magnetic field in Gauss	Magnetic field in Tesla
01	0.5		
02	1.0		
03	1.5		
04	2.0		
05	2.5		
06	3		
07	3.5		

11 Now plot the graph between magnetic field and current.

12 You can observe all reading on software screen and real time Curve of variation in magnetic field with changing current.

Results: The magnetic field increase with increasing the current of electromagnet.

Experiment 2

Objective : Find the poles of electromagnet with the help of InAs probe

Items Required

1. Electromagnet
2. Gauss and Tesla meter Nvis 621
3. Hall probe (InAs)
4. Constant Current Power supply Nvis 623.

Procedure

1 Take Gauss & Tesla meter from the set of Hall Effect Setup .

2. Connect InAs probe and switch on the Gauss & Tesla meter.

3 Adjust zero reading on display by Zero Adjust potentiometer and keep range selector switch at X1 position.

4 Now take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.

5. Switch on the power supply & set some low value of current.

6 Keep Hall probe (InAs) between electromagnet such that the flat face (Inner part of shielded probe) of the probe is kept perpendicular to the direction of magnetic field. Note the strength of magnetic field.

7 Increase the current from the Constant Current Power Supply and note the value of corresponding magnetic field. If magnetic field is greater than 2k Gauss then meter will indicate the over range. For its measurement keep the selector switch at X10 position and note the value of magnetic field.

8. Multiply the display reading by 10 to get the magnetic field strength in both Gauss and Tesla unit.

9 Direction of magnetic field: If the magnetic field indicated by the Gauss meter is positive (without sign), the pole facing the side of the InAs probe marked N is North Pole and the other side is South pole.

Experiment 3

Objective: To measure the Hall voltage

Items Required

1 Gauss and Tesla meter Nvis 621

2 Measurement unit Nvis 622

3 Constant current power supply Nvis 623

4 Electromagnet

5 Hall probe

6 In As probe.

Procedure

1 Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.

2 Keep the Poles of electromagnet at some distance of 20mm.

3. Take Gauss & Tesla meter from the set of Hall Effect Setup .

4. Connect In As probe and switch on the Gauss & Tesla meter.

5. Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.

6 Now take measurement unit and set it as follows

- Heater current potentiometer at minimum position (anticlockwise position).
- Probe current potentiometer at minimum position (anticlockwise position).

7. Connect Hall Probe in given probe socket (Nvis 622).

8. Switch on the Constant Current Power supply and set some low value of current.

9. Switch on the Measurement unit and increase probe current by probe current potentiometer and fix it at 5mA.

10. There may be some voltage reading even outside the magnetic field. This is due to imperfect arrangement of the four contact of the hall probe and generally known as the “Zero field potential. In all cases, this error should be subtracted from the hall voltage reading as we consider it as a reference.

11 Now place the Hall probe between magnetic poles using stand such that the magnetic and electric field should be perpendicular to each other.

12. Due to this arrangement a force is generated in semiconductor, therefore a potential difference is developed in semiconductor wafer, which is perpendicular of both field (magnetic and electric). This potential difference is called Hall voltage.

13 You can measure & record this potential difference on the display (Nvis 622).

14 Measure Hall voltage for both sides of probe

15 Subtract Zero field potential and take the mean of both sides Hall voltages readings. This is Hall voltage V_H

Observation Table

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{Zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V^+ = V_H^+ - V_{zero}$)	Hall voltage for second side without offset voltage ($V^- = VH^- - V0$)	Mean Voltage VH = $\frac{V^+ - V^-}{2}$

Experiment 4

Objective: Calculate the charge carrier concentration (density) of given semiconductor wafer

Items Required

1 Gauss and Tesla meter Nvis 621
2. Measurement unit Nvis 622
3. Constant current power supply Nvis 623
4. Electromagnet
5. Hall probe
6. In As probe.

Procedure

1. Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
2. Keep the Poles of electromagnet at some distance of 20mm.
3. Take Gauss & Tesla meter from the set of Hall Effect Setup .
4. Connect InAs probe and switch on the Gauss & Tesla meter.
5. Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.
6. Now take measurement unit and set the switch position as follows
   - Heater current potentiometer at minimum position (anticlockwise position).
   - Probe current potentiometer at minimum position (anticlockwise position).
7. Connect Hall Probe in given probe socket (Nvis 622).
8. Switch on the Constant Current Power supply and set some low value of current.
9. Switch on the Measurement unit and increase probe current by probe current potentiometer and fix it at 5mA.
10. There may be some voltage reading even outside the magnetic field. This is due to imperfect arrangement of the four contact of the hall probe and generally known as the "Zero field potential. In all cases, this error should be subtracted from the hall voltage reading as we consider it as a reference.

11 Now place the Hall probe between magnetic poles using stand such that the magnetic and electric field should be perpendicular to each other.

12 Due to this arrangement a force is generated in semiconductor, therefore a potential difference is developed in semiconductor wafer, which is perpendicular of both field (magnetic and electric). This potential difference is called Hall voltage.

13\. You can measure & record this potential difference on the display.

14\. Measure Hall voltage for both sides of probe

15\. Subtract Zero field potential and take the mean of both sides Hall voltages readings. This is Hall voltage V_H.

Observation Table

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{Zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V^+ = V_H^+ - V_{zero}$)	Hall voltage for second side without offset voltage ($V^- = V_H^- - V0$)	Mean Voltage $V_H = \frac{V^+ - V^-}{2}$

16. Now we know that charge carrier density n can be calculated by

$$n = B \times I / V_H \times t \times e$$

Where

n = carrier concentration,

B = magnetic field

I = current of probe

V_H = Hall voltage

t = Width of Hall crystal= Mention on the Hall Probe

e = Electron charge=1.6×10^{-19} coulomb

Now put the all value in formula and calculate the charge carrier density.

Experiment 5

Objective : Calculate the Hall coefficient of given semiconductor material

Items Required

1 Gauss and Tesla meter Nvis 621

2 Measurement unit Nvis 622

3. Constant current power supply Nvis 623

4. Electromagnet

5 Hall probe

6 In As probe

Procedure

Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.

Take Gauss & Tesla meter from the set of Hall Effect Setup.

Connect InAs probe and switch on the Gauss & Tesla meter.

Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.

Keep the Poles of electromagnet at some distance of 20mm.

Now take measurement unit and set the switch position as follows

- Heater current potentiometer at minimum position (anticlockwise position).
- Probe current potentiometer at minimum position (anticlockwise position).

Connect Hall Probe in given probe socket (Nvis 622).

Switch on the Constant Current Power supply and set some low value of current.

Switch on the Measurement unit and increase probe current by probe current potentiometer and fix it at 5mA.

There may be some voltage reading even outside the magnetic field. This is due to imperfect arrangement of the four contact of the hall probe and generally known as the “Zero field potential. In all cases, this error should be subtracted from the hall voltage reading as we consider it as a reference.

Now place the Hall probe between magnetic poles using stand such that the magnetic and electric field should be perpendicular to each other.

Due to this arrangement a force is generated in semiconductor, therefore a potential difference is developed in semiconductor wafer, which is perpendicular of both field (magnetic and electric). This potential difference is called Hall voltage.

Nvis 6101 Hall Effect Setup

You can measure & record this potential difference on the display.

Measure Hall voltage for both sides of probe

Subtract Zero field potential and take the mean of both sides Hall voltages readings. This is Hall voltage V_H

Now we know that charge carrier density n can be calculated by

Observation table

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{Zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V_+ = V_H^+$ - Vzero)	Hall voltage for second side without offset voltage ($V_- = V_H^- - V_{Zero}$)	Mean Voltage $V_H = \frac{V^+ - V^-}{2}$

$$n = B \times I / VH \times t \times e$$

Where

N = carrier concentration

B = magnetic field

I = current of probe

VH = Hall voltage

t = Width of Hall crystal= Mention on the Hall Probe

e = Electron charge=1.6×10^{-19} coulomb

Now put the all value in formula and calculate the charge carrier density.

Now for calculating the hall coefficient we have to use following formula

$$R_H = 1/ne$$

Where

R_H = Hall coefficient,

n = Carrier concentration
or carrier density e =
Electron charge

Put the value of n and e and find the hall coefficient.

Experiment 6

Objective: Calculate the mobility of charge carrier (μ)

Items Required

1 Gauss and Tesla meter Nvis 621

2 Measurement unit Nvis 622

3 Constant current power supply Nvis 623

4. Electromagnet

5. Hall probe

6 InAs probe

1. **Procedure**
2. Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
3. Take Gauss & Tesla meter from the set of Hall Effect Setup .
4. Connect In As probe and switch on the Gauss & Tesla meter.
5. Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.
6. Keep the Poles of electromagnet at some distance of 20mm.
7. Now take measurement unit and set the switch position as follows
    - Heater current potentiometer at minimum position (anticlockwise position).
    - Probe current potentiometer at minimum position (anticlockwise position).
8. Connect Hall Probe in given probe socket (Nvis 622).
9. Switch on the Constant Current Power supply and set some low value of current.
10. Switch on the Measurement unit and increase probe current by probe current potentiometer and fix it at 5mA.
11. There may be some voltage reading even outside the magnetic field. This is due to imperfect arrangement of the four contact of the hall probe and generally known as the "Zero field potential. In all cases, this error should be subtracted from the hall voltage reading as we consider it as a reference.

11 Now place the Hall probe between magnetic poles using stand such that the magnetic and electric field should be perpendicular to each other.

12 Due to this arrangement a force is generated in semiconductor, therefore a potential difference is developed in semiconductor wafer, which is perpendicular of both field (magnetic and electric). This potential difference is called Hall voltage.

13 You can measure & record this potential difference on the display.

14 Measure Hall voltage for both sides of probe

15 Subtract Zero field potential and take the mean of both sides Hall voltages readings. This is Hall voltage V_H.

Observation Table

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{Zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V_+ = V_H^+ - V_{Zero}$)	Hall voltage for second side without offset voltage ($V_- = V_H^- - V_{Zero}$)	Mean Voltage $VH = \frac{V^+ - V^-}{2}$

16 Now we know that charge carrier density n can be calculated by

$$n = B \times I / V_H \times t \times e$$

Where n = carrier concentration

B = magnetic field

I = current of probe

V_H = Hall voltage

t = Width of Hall crystal = Mention on the Hall Probe

e = Electron charge=1.6×10^{-19} coulomb

Now put all the values in formula and calculate the charge carrier density.

17 Now for calculating the hall coefficient we have to use following formula

$$R_H = 1/ne$$

Where R_H = Hall coefficient,

n = Carrier concentration or carrier density

e = Electron charge

Put the value of n and e and find the hall coefficient.

18 Now we know that carrier mobility

$$\mu = \sigma R_H$$

Where σ = conductivity

And we also that

$\sigma = 1/\rho$

It is specified that the resistivity of the given Ge crystal is

ρ = "Mention on the Hall Probe" Ω cm

Put the value of R_H and ⍰ and find mobility.

Experiment 7

Objective: Measure Hall voltage as a function of probe current at constant magnetic field

Items Required

1 Gauss and Tesla meter Nvis 621
2. Measurement unit Nvis 622
3. PC Interface S/W (Nvis 622)
4. Constant current power supply Nvis 623
5. Electromagnet
6. Hall probe
7. In As probe.

Procedure

1. Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
2. Keep the Poles of electromagnet at some distance of 10mm (for InAs Probe).
3. Now take measurement unit and set the switch position as follows
   - Heater current potentiometer at minimum position (anticlockwise position).
   - Probe current potentiometer at minimum position (anticlockwise position).
4. Connect Hall Probe in given probe socket (Nvis 622).
5. Take Gauss & Tesla meter from the set of Hall Effect Setup .
6. Connect InAs probe and switch on the Gauss & Tesla meter.
7. Adjust zero reading on display by Zero Adjust potentiometer.
8. Switch on the Constant Current Power supply and set some value of current such that the magnetic field is near about 1K Gauss.
9. Switch on the measurements unit and set probe current at 1mA.
10. Take the Hall voltage reading when there is no magnetic field notes it as Zero field potential.

11. Now Keep the Poles of electromagnet at some distance of 20mm (for Hall Probe).
12. Now place hall probe in magnetic field with using stand support and take Hall voltages in both sides of probe.
13. Take the reading as shown in table.

Observation Table

Constant Magnetic field = Gauss

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V^+ = V_H^+ - V_{zero}$)	Hall voltage for second side without offset voltage ($V^- = V_H^- - V_{zero}$)	Mean Voltage $V_H = \frac{V^+ - V^-}{2}$
1mA							
2mA							
3mA							
4mA							
5mA							
6mA							
7mA							

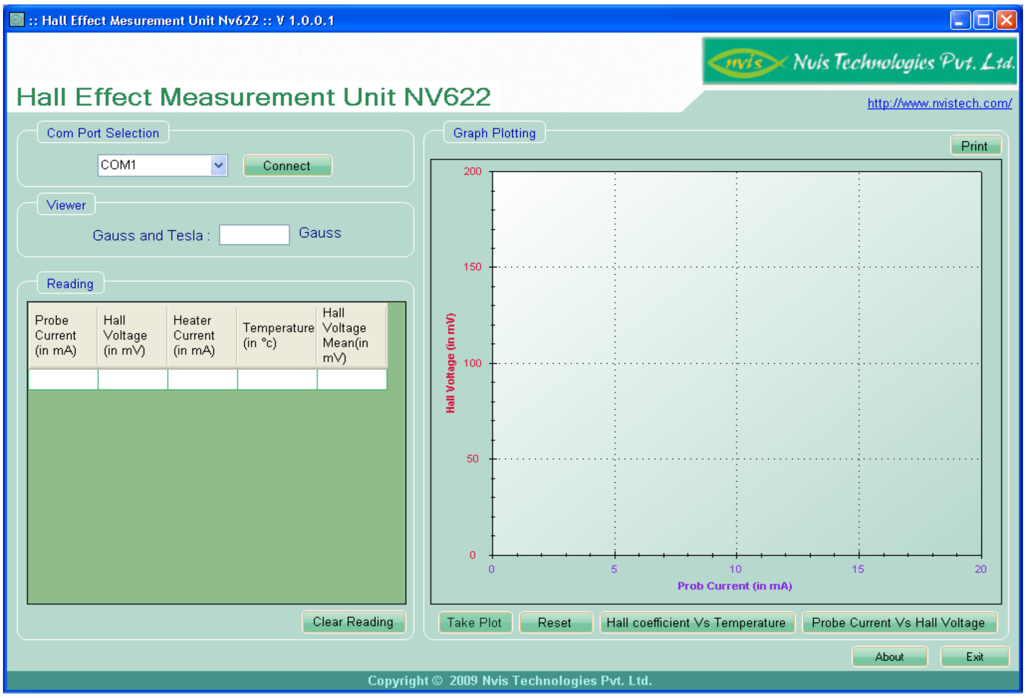
14 Measure Hall voltage as per the given table for each current

15. Now plot the graph between Mean Hall voltages and probe current.

Nvis 6101 Hall Effect Setup

Procedure for performing Experiment with the help of Nvis 622 software

1. Install the software provided with the setup. (If not done already)
2. Open the software window by double clicking on its icon
3 Following window will appear on your computer screen, as you open the software.

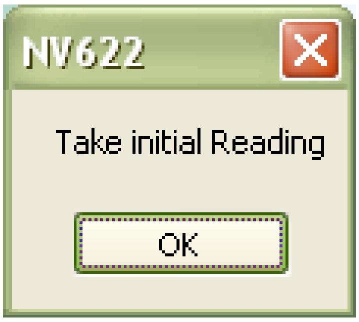


4 Then follow the above procedure from step 1 to 9.

5. Now Keep the Poles of electromagnet at some distance of 20mm (for Hall Probe).

6 Now connect the instrument to the computer using RS232 cable or USB cable.

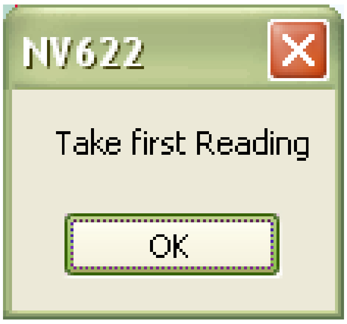
7. Select the appropriate com port & connect the device with PC.
8. Click on “Probe Current v/s Hall Voltage” button on the software window.
9. Take initial reading” window will appear, press ok button.



Take initial Reading

10 For taking the Hall voltage reading when there is no magnetic field then click “Take reading” button as Zero field potential.

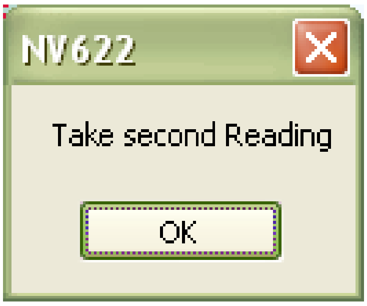
11 After this “Take first reading” window will appear, press ok button.



Take first Reading

12 Now place hall probe in magnetic field with using stand support & now click again” Take reading” button for taking the first reading of Hall voltage.

13 After this “Take second reading” window will appear, press ok button.



Take second Reading

14 Now place reverse the side of Hall Probe in magnetic field then again click “Take reading” button for taking the second reading of Hall voltage.

15 Similarly keep on taking the readings for varying value of current.

16 Software will now perform the necessary calculation and will plot the graph between probe current and Hall voltage.

17 Print of this graph can also be taken through provided print option.

Experiment 8

Objective: Measure Hall Voltage as a function of magnetic field at constant Hall probe current

Items Required

1 Gauss and Tesla meter Nvis 621

2 Measurement unit Nvis 622

3 Constant current power supply Nvis 623

4 Electromagnet

5 Hall probe

6 In As probe.

Procedure

1 Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.

2 Keep the Poles of electromagnet at some distance of 20mm.

3. Take Gauss & Tesla meter from the set of Hall Effect Setup .

4 Connect In As probe and switch on the Gauss & Tesla meter.

5 Adjust zero reading on display by Zero Adjust potentiometer.

6. Set the magnetic field of Electromagnet for 500 Gauss with the help of Constant Current Power Supply & Gauss & Tesla meter.

7 Now take measurement unit and set the switch position as follows

- Heater current potentiometer at minimum position (anticlockwise position).
- Probe current potentiometer at minimum position (anticlockwise position).

8 Connect Hall Probe in given probe socket (Nvis 622).

9 Switch on the measurements unit and set the probe Current at 5mA. Take the Hall voltage reading when there is no magnetic field & note it as Zero field potential.

10 Now place Hall probe in magnetic field and take Hall voltage in both the sides of probe.

11 Take the reading as shown in table by increasing the magnetic field of electromagnet.

Nvis 6101 Hall Effect Setup

Observation Table

Probe current = ...mA Zero state voltage =.....mV

Probe Current I(mA)	Magnetic Field B(Tesla)	Zero field Potential (offset voltage) V_{Zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V_+ = V_H^+ - V_{Zero}$)	Hall voltage for second side without offset voltage ($V_- = V_H^- - V_{Zero}$)	Mean Voltage VH = $\frac{V^+ - V^-}{2}$
	500						
	1K						
	1.5K						
	2K						
	2.5K						
	3K						

12. Measure Hall voltage as per given table for each magnetic field.
13. Now plot the graph between Hall voltages and magnetic field.

Experiment 9

Objective: Study of the dependence of Hall coefficient on Temperature

Items Required

1 Gauss and Tesla meter Nvis 621

2 Measurement unit Nvis 622

3 PC Interface S/W (Nvis 622)

4 Constant current power supply Nvis 623

5 Electromagnet

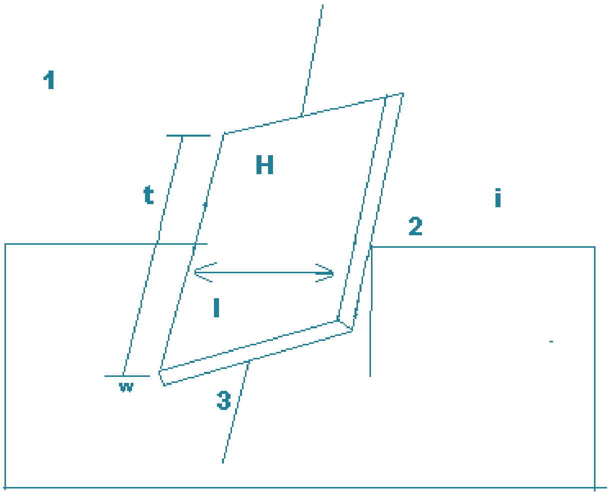
6 Hall probe

7 InAs probe.

Theory E.H.:

Hall discovers in 1879 Conductivity measurements in semiconductors, can not reveal whether one or both types of character are present, nor distinguish between them. However, this information can be obtained from Hall Effect measurements, which are a basic tool for the determination of the mobility.

Consider a simple crystal mounted as in the Fig. with a magnetic field H in the Z direction perpendicular to 1, 2, 3 and 4.if current is flowing through the crystal in X-direction by application of Voltage V between 1 and 2 .A voltage will appear across contact 3and 4 .It is easy to calculate this voltage if it is assume that all carrier have the same drift velocity. We will do this in two steps: 1) By assuming that carrier only one type is present and 2) By assuming that carrier of both types are present.



Nvis 6101 Hall Effect Setup

Arrangement for the measurement of Hall Effect in semiconductor crystal

We know that conduction in solids due is due to the motion of the charges carrier under the influence of an applied field .we define the following symbol:

J = current density

σ = conductivity, such that σ E = J, σ = 1/ρ = receptivity

e = charge of the electron

n = negative carrier density,

p = positive carrier density

v = drift velocity

E = applied electric field

μ = mobility, such that μ E=v

M = effective mass m_e, m_h for electron, holes

λ = mean free path between collision

a) **One type carrier:** The magnetic force on the carrier is $F_m = e\,(v \times H)$ and it is compensated by the hall field $F_H = eE_H$ = e Eyiy thus $vH = E_y$ but $v = \mu E_X$. The Hall coefficient R_H is defined as

$$|R_H| = \frac{E_y}{J_X H} = \frac{\mu E_X}{J_X} = \frac{\mu}{\sigma} = \frac{1}{ne}$$

Hence for fixed magnetic field and fixed input current ,the hall voltage is proportional to 1/n .it follows that

$$\mu H = R_{H\sigma}$$

Providing an experimental measurement of the mobility; R_H is expressed in cm^3 $coulumb^{-1}$ and σ $inohm^{-1}cm^{-1}$, thus μ is expressed in units of cm^2 $volt^{-1}sec^{-1}$

In case the voltage across the input is kept constant, it is convenient to define the hall angle as the ratio of applied and measured voltage

$$\phi = \frac{V_Y}{V_X} = \frac{E_Y t}{E_X l} = \mu \frac{t}{l} H$$

Where l is the length and t the thickness of the crystal, The Hall angle is proportional to the mobility, and

$$\rho V_y = \left(\frac{t}{l}\, H\right)\frac{1}{ne}$$

is again proportional to 1/n and thus to $|R_H|$

b) **Two type of carriers :** Now it is important to recognize that the same electric field Ex, the Hall voltage for p carriers will have opposite sign from that for n carriers (that is, the Hall coefficient R has a different sign) Thus, the Hall field Ey will not be able to compensate for the magnetic force on both types of carriers and there will be a transverse motion of carriers; however, the net transverse transfer of charge will remain zero since there is no current through the 3, 4 contacts; this statement is expressed as

$$e(V_X^+ n - V_Y^- n) = 0$$

$$e(V_X^+ n - V_X^- p) = J_X \text{ and } e(\mu^+ p + \mu^- n) = \sigma$$

Where the mobility is always a positive number; however, Vx^{+} has the opposite sign from Vx^{-}, but

$$V_Y = \frac{s}{t} = \left(\frac{1}{2}\frac{F}{m}t^2\right)\frac{1}{t}$$

Where

$$F^+ = e\left[(V_X^+ \times H) - E_y\right]$$
$$F^- = -e\left[(V_X^- \times H) - E_y\right]$$

Thus

$$V_y^+ = \frac{1}{2}\frac{e}{m_e}t\left[(\mu^+ E \times H) - E_Y\right] = \mu^+\left(\mu^+ E \times H - E_y\right)$$
$$V_y^- = \frac{1}{2}\frac{e}{m_e}t\left[(\mu^- E \times H) - E_Y\right] = \mu^-\left(\mu^- E \times H - E_y\right)$$

And thus

$$\mu^+ p\left(\mu^+ E \times H - E_y\right) - \mu^- n\left(\mu^- E \times H + E_y\right) = 0$$

$$E_Y = E \times H\,\frac{(\mu h^2 p - \mu e^2 n)}{\mu h p + \mu e n}$$

And for the Hall Coefficient R_H

$$R_H = \frac{E_y}{J \times H} = \frac{E_y}{\sigma E \times H} = \frac{\mu h^2 p - \mu e^2 n}{e(\mu h p + \mu e n)^2}$$

Since the nobilities µh are not constants but functions of T, The Hall is also a function of T and it may become Zero and even change sign. In general µe < µh so that inversion may happen only if p> n; thus “Hall coefficient inversion “is characteristics of only “P- type”

Nvis 6101 Hall Effect Setup

Procedure:

1. Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
2. Keep the Poles of electromagnet at some distance of 20mm.
3. Take Gauss & Tesla meter from the set of Hall Effect Setup .
4. Connect In As probe and switch on the Gauss & Tesla meter.
5. Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.
6. Set the magnetic field of Electromagnet between 500 Gauss & 3000 Gauss with the help of Constant current power supply & Gauss & Tesla meter. (Suppose we set magnetic field 1K Gauss)
7. Now take measurement unit and set the switch position as follows
    - Heater current potentiometer at minimum position (anticlockwise position).
    - Probe current potentiometer at minimum position (anticlockwise position).
8. Connect Hall Probe in given probe socket (Nvis 622).
9. Switch on the measurements unit and set Probe Current at 5mA.

10 Take the Hall voltage reading when there is no magnetic field & note it as Zero field potential.

11 Now place Hall probe in magnetic field and take Hall voltage for both the sides of probe. Record your results in following table for no Heater current.

12 Set the heater current at maximum position.

13 For measure Hall voltage corresponding to the change in temperature keeps on taking reading at the fixed interval of temperature.

14 Measure and record the reading as shown in table.

Observation table

Sample	:	Ge (p-type) medium doping
Thickness	:	Mention on the Hall Probe
Magnetic Field	:	1K Gauss
Probe Current	:	5 mA
Heater Current	:	mA

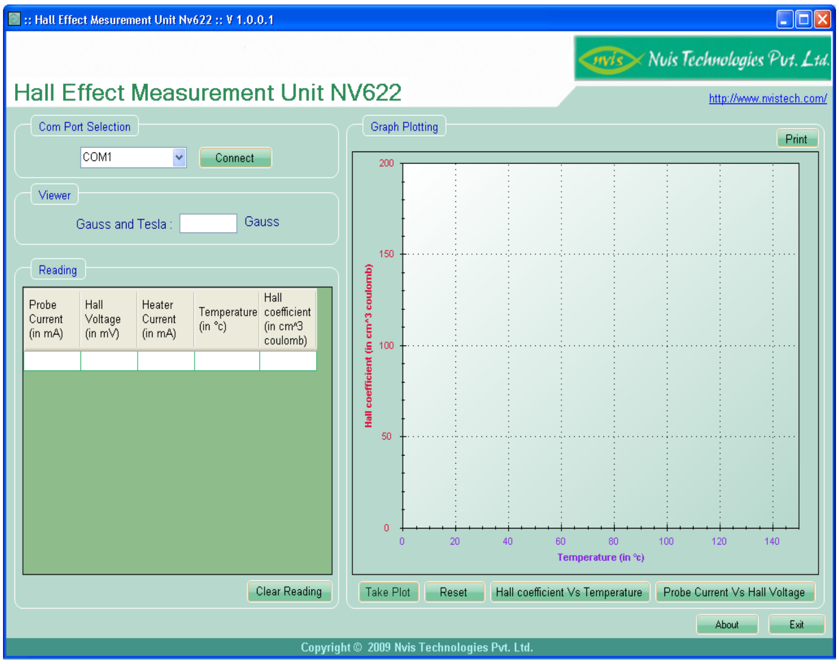
Nvis 6101 Hall Effect Setup

Temperature (°C)	Zero field Potential (offset voltage) V_{zero}	Hall voltage for one side of the probe With offset Voltage (V_H^+)	Hall Voltage for Second side with offset Voltage (V_H^-)	Hall voltage for one side without Offset voltage ($V^+ = V_H^+ - V_{zero}$)	Hall voltage for second side without offset voltage ($V^- = V_H^- - V_{zero}$)	Mean Voltage $V_H = \frac{V^+ - V^-}{2}$	Hall Coefficient Cm^3/ Coulomb
25^{0}C(room temp)							
28 ^{0}C							
31 ^{0}C							
34 ^{0}C							
37 ^{0}C							
40 ^{0}C							
43 ^{0}C							
46 ^{0}C							
49 ^{0}C							
52 ^{0}C							
55 ^{0}C							

15 Calculate Hall Coefficient for each value of temperature and record it into the table. Plot the Graph between Hall Coefficient and Temperatur

Procedure for performing Experiment with the help of Nvis 622 software

1. Install the software provided with the setup. (If not done already).
2. Open the software window by double clicking on its icon
3. Following window will appear on your computer screen, as you open the software.



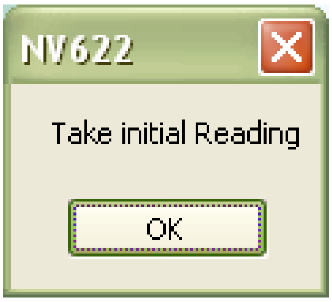
4 Then follow the above procedure from step 1 to 9.

5 Now connect the instrument to the computer using RS232 cable or USB cable.

6 Select the appropriate com port & connect the device with PC.

7 Click on “Hall coefficient v/s Temperature” button on the software window.

8\. “Take initial reading” window will appear, press ok button.

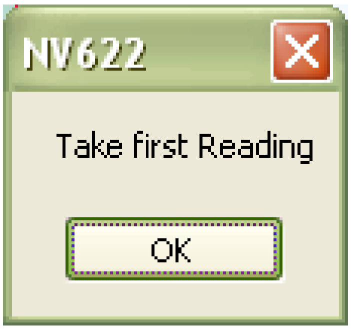


Take initial Reading

9 Now first enter the Magnetic Field (1000 Gauss) in the given text box on the window.

10 For taking the Hall voltage reading when there is no magnetic field & no heater current then click “Take reading” button as Zero field potential.

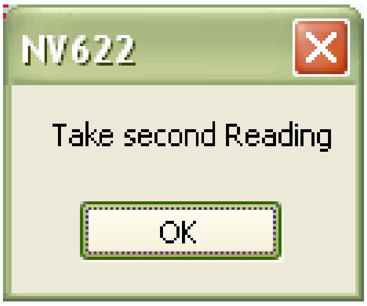
11 After this “Take first reading” window will appear, press ok button.



Take first Reading

12 Now place hall probe in magnetic field with using stand support & now click again” Take reading” button for taking the first reading of Hall voltage.

13 After this “Take second reading” window will appear, press ok button.



Take second Reading

14 Now place reverse the side of Hall Probe in magnetic field then again click "Take reading" button for taking the second reading of Hall voltage.

15 Set the heater current at maximum position then the temperature of the will keep on increasing.

16 Now for measure Hall voltage corresponding to the change in temperature keeps on taking reading at the fixed interval of temperature.

17 Software will now perform the necessary calculation and will plot the graph between Hall Coefficient and temperature.

18 Print of this graph can also be taken through provided print option.

Sample reading

Experiment 1

Observation Table:

Sr. No.	Current (A)	Magnetic field in Gauss	Magnetic field in Tesla
1	0.5	505	0.0505
2	1	715	0.0715
3	1.5	970	0.97
4	2	1178	0.1178
5	2.5	1382	0.1382
6	3	1507	0.1507
7	3.5	1615	0.1615

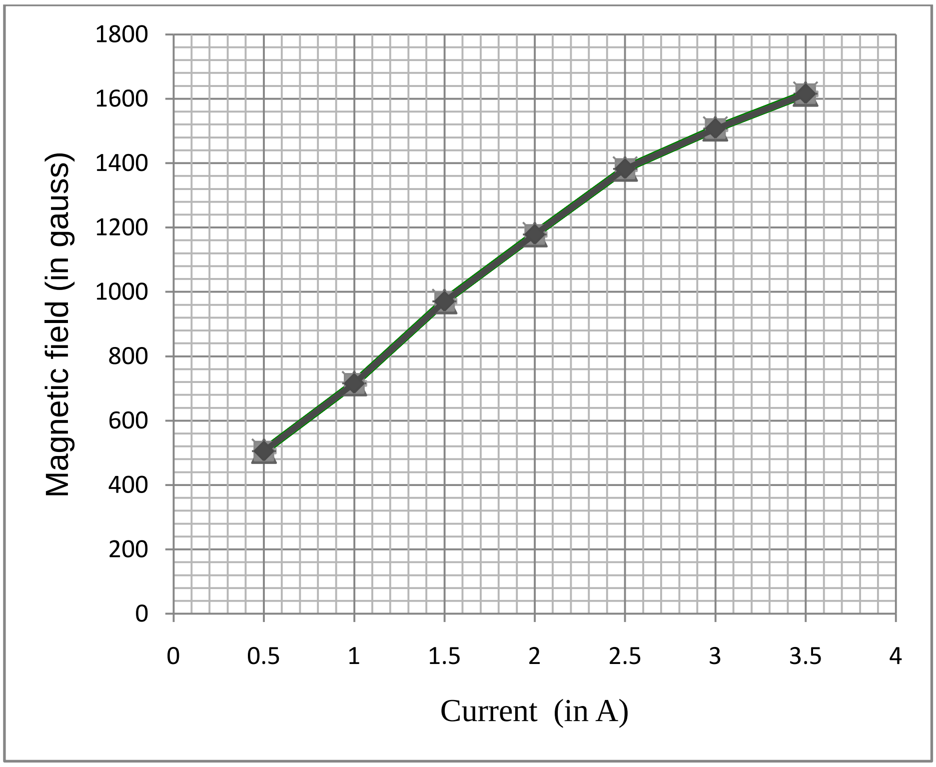


Figure : The graph between applied current and magnetic field generated by a electromagnet

Experiment 3

Objective: Calculate the value of Hall Voltage

Observation Table:

Probe Current I(mA)	Magnetic Field B(Gauss)	Zero field Potential (offset voltage) Vzero	Hall voltage for one side of the probe With offset voltage (V_H^+)	Hall Voltage for Second side with offset voltage (V_H^-)	Hall voltage for one side Without offset voltage $(V^+=V_H^+-0)$	Hall voltage for Second side Without offset voltage $(V^-=V_H^-V0)$	Mean Hall voltage $V_H = \frac{V^+ - V^-}{2}$
5 mA	1150	74 mV	80.4mV	68 mV	6.4 mV	6 mV	6.2 mV

Experiment 4

Objective: determination of carrier concentration

Observation Table:

Probe Current I(mA)	Magnetic Field B(Gauss)	Zero field Potential (offset voltage) Vzero	Hall voltage for one side of the probe With offset voltage (V_H^+)	Hall Voltage for Second side with offset voltage (V_H^-)	Hall voltage for one side Without offset voltage $(V^+=V_H^+- 0)$	Hall voltage for Second side Without offset voltage $(V^-=V_H^-V0)$	Mean voltage $V_H = \frac{V^+ - V^-}{2}$
5 mA	1150	74 mV	80.4 mV	68 mV	6.4mV	6 mV	6.2 mV

Formula Used:

Charge Carrier Density

$n = B \times I / V_H \times t \times e$

Where,

B = magnetic field = 0.115 Tesla

I = current of probe = 0.005 A

V_H = Hall voltage = 0.0062 V

t = Width of Hall crystal = 0.75 mm = 0.00075 meter (as on probe)

e = Electron charge = 1.6×10^{-19} coulomb

Substituting the values in of carrier formula concentration we have:

n = carrier concentration $=7.72 \times 10^{20}$

Experiment 5

Using the value of Carrier concentration or carrier density from experiment 4 and substituting the values in below formula we have

Hall coefficient R_H = 1/ne

Where,

n = Carrier concentration carrier density = 7.72×10^{20} /m3

e = Electron charge, = 1.6×10^{-19}coulomb

On substituting the values in above formula we have

Hall coefficient R_H = 0.80×10^{-2} m^3 / Coulomb

Experiment 6

Carrier Mobility μ = σ X RH

Where,

σ = conductivity = σ = 1/ρ

Resistivity of the Ge crystal is ρ = 6 Ω cm = 0.06 Ω m (given on probe)

σ = 1/0.06

= 16.666 / Ω m

Hall coefficient R_H = 0.8×10^{-2} m3 / Coulomb (as calculated in experiment 5)

Substituting the value of σ and R_H in formula for mobility we have

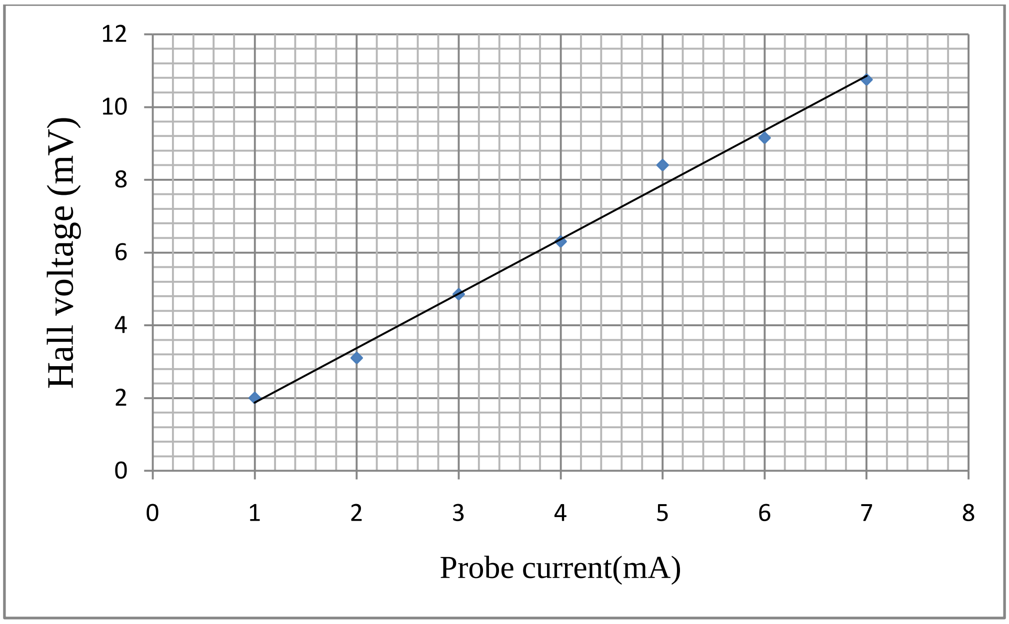
$\mu = 16.66 \text{ X } 0.8 \text{x} 10^{-2} = 13.33 \times 10^{-2}$

Carrier Mobility $\mu = 13.33 \times 10^{-2}$

Experiment 7

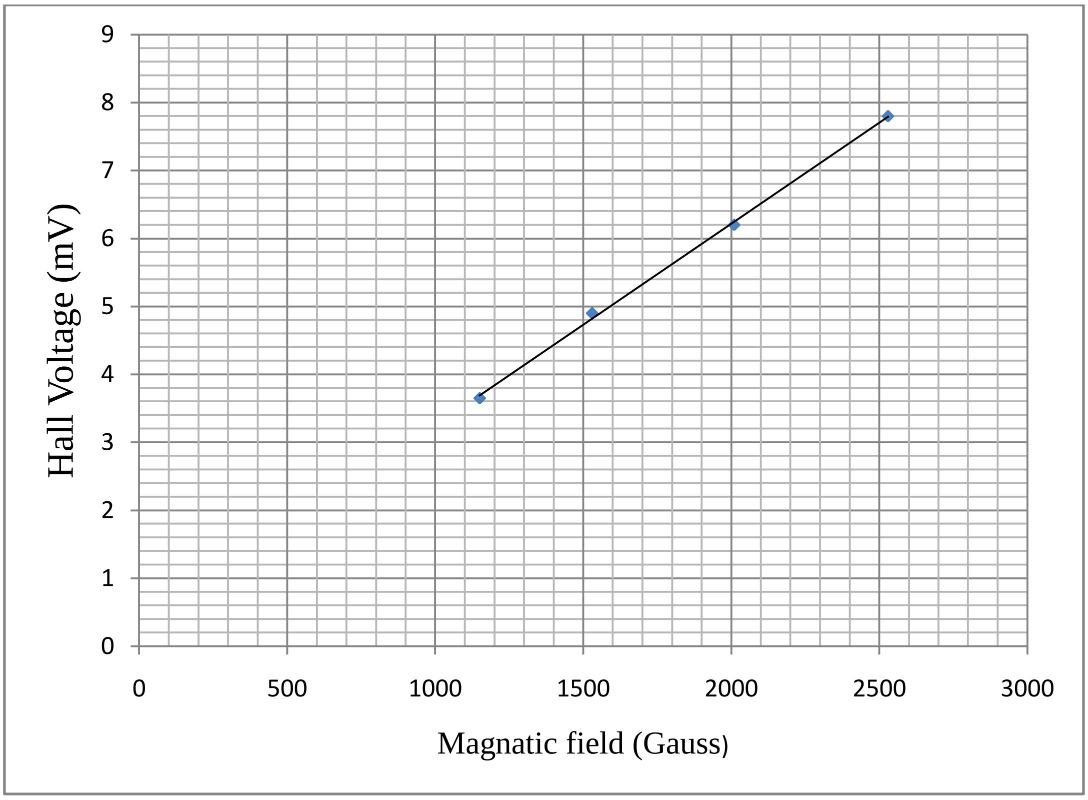
Observation Table:

Probe Current I(mA)	Magnetic Field B(Gauss)	Zero field Potential (offset voltage) Vzero	Hall voltage for one side of the probe With offset voltage (V_H^+)	Hall Voltage for Second side with offset voltage (V_H^-)	Hall voltage for one side Without offset voltage ($V_+ = V_H^+ - 0$)	Hall voltage for Second side Without offset voltage ($V^- = V_H - V_{Zero}$)	Mean voltage $V_H = \frac{V^+ - V^-}{2}$
1.13 mA	2410	13.6	16	12	2.4	1.6	2
1.95 mA	2410	26.4	29.6	23.4	3.2	3	3.1
3.07 mA	2410	43.9	49.1	39.4	5.2	4.5	4.85
3.95 mA	2410	57.5	64	51.4	6.5	6.1	6.3
4.95 mA	2410	73.2	81.4	64.6	8.2	8.6	8.4
6 mA	2410	88.9	98.4	80.1	9.5	8.8	9.15
7 mA	2410	103.6	114.8	93.3	11.2	10.3	10.75



Experiment 8

Probe Current	Magnetic Field	Zero field Potential (offset voltage)	Hall voltage for one side of the probe With offset voltage	Hall Voltage for Second side with offset voltage	Hall voltage for one side Without offset voltage	Hall voltage for Second side Without offset voltage	Mean voltage $V_H = \frac{V^+ - V^-}{2}$
I(mA)	B(Gauss)	V_{Zero}	(V_H^+)	(V_H^-)	($V^+ = V_H + -0$)	($V- = V_H — V_0$)	
5	1530	74	79.1	69.3	5.1	4.7	4.9
5	1150	74	77.8	70.5	3.8	3.5	3.65
5	2010	73.9	80.4	68	6.5	5.9	6.2
5	2530	73.6	82.3	66.7	8.7	6.9	7.8



Experiment 9

Probe Current	Magnetic Field	Zero field Potential (offset voltage)	Hall voltage for one side of the probe With offset voltage	Hall Voltage for Second side with offset voltage	Hall voltage for one side Without offset voltage	Hall voltage for Second side Without offset voltage	Mean voltage $V_H = \frac{V^+ - V^-}{2}$	Temperature (^{0}C)	Hall Coefficient Cm^3 / Coulumb
I(mA)	B(Gauss) in K	Vzero	(V_H^+)	(V_H^-)	($V^+=V_H^+ - 0$)	($V^-=V_H^- V0$)			
5	1	88	68	106	20	18	19	30	0.0304
5	1	88	72	108	16	20	18	33	0.0288
5	1	88	72	107	16	19	17.5	36	0.028
5	1	88	74	107	14	19	16.5	39	0.0264
5	1	88	74	104.5	14	16.5	15.25	42	0.0244
5	1	88	75	103	13	15	14.00	45	0.0224
5	1	88	75	100	13	12	12.5	48	0.02
5	1	88	74	100	14	12	13.00	51	0.0208
5	1	88	74	98	14	10	12.00	53	0.0192
5	1	88	73	96	15	8	11.5	55	0.0184

Glossary

1. **Conductor.** It is a type of material in which charge carriers (effectively electrons or holes) can be made to flow with arbitrarily small voltages. A conductor is distinguished by having a partially filled conduction band, and, hence, no gaps between the highest occupied and the lowest unoccupied electronic states. Common examples of conductors are copper and iron.

2. **Electron Concentration.** It is the number of electrons per unit volume in the conduction band of the material.

3. **Extrinsic material.** It is a material whose number of electrons is not equal to the number of holes (positive carriers).

4. **Hall coefficient.** It is a parameter that measures the magnitude of the Hall Effect in the sample. It has units of $\frac{\Omega m}{Tesla}$. (Contrast this with resistivity, which has units of Ωm.) The Hall coefficient is defined as $R_H = \frac{E}{JB}$ where *E*, *J*, and *B* are the magnitudes of the electric field, the current density, and the magnetic field, respectively. In the experimental setup to determine the Hall coefficient, these three vectors are mutually perpendicular.

5. **Hall Effect.** It is a phenomenon that occurs when a conductor or semiconductor is placed in the magnetic field and a voltage (i.e. the electric field in the above definition) is applied through the material perpendicular to the magnetic field. While this voltage induces current flow along the electric field direction, the charge carriers also experience a magnetic deflection from their path. This results a separation of positive and negative carriers, and thus the generation of an electric field perpendicular to the direction of current flow. Note that, at sufficient temperature, the net current in a semiconductor is made up of counteracting currents of p-type and n-type carriers

6. **Hall field.** It is an electric field perpendicular to the direction of current flow generated by the Hall Effect.

7. **Hall voltage.** It is the potential difference across the semiconductor that is produced by the Hall field. This is the voltage which is exactly enough to compensate for the deflection of charge carriers by the magnetic field, so that the net current perpendicular to the applied voltage is zero.

8. **Hole.** It is an effective positively charged "empty state." The description of current in terms of the motion of positively charged holes rather than negatively charged electrons is convenient and accurate when describing a material with an almost filled conduction band.

9. **Hole Concentration.** It is the number of holes (positive carriers) per unit volume in the conduction band of the material.
10. **Intrinsic Material.** It is a material in which the number of negative carriers (electrons) is the same as the number of positive carriers (holes).
11. **Insulator.** It is a material in which electrons cannot be made to flow with low voltages. Using the quantum mechanical description of periodic solids, insulators are characterized by having completely filled valence bands, and large energy gaps to the lowest-lying unoccupied conduction bands.
12. **Drift mobility.** It is the drift velocity per unit applied electric field, $\mu_d = \frac{\nu_d}{E}$.
13. **Drift velocity.** It is the average velocity in the direction of an applied electric field of the all conducting charge carriers in the sample.
14. **Lorentz force.** It is the force, $\vec{F} = q(\vec{\nu} \times \vec{B})$ which a moving charge experiences when subjected to a magnetic field. Here, $\vec{B}$ is the magnetic field, $\vec{\nu}$ is the velocity of the carrier, and *q* its charge.
15. **N-type material.** It is a material in which the negatively (n) charged carriers are mostly responsible for the conduction.
16. **P-type material.** It is a material in which the positively (p) charged carriers are mostly responsible for the conduction.
17. **Resistivity.** It is a material parameter that is a measure of the resistance to current. The resistivity is defined as the resistance of the sample times the cross sectional area of the sample divided by the length of the sample, $\rho = \frac{RA}{l}$. The resistivity has units of Ωm and it is inversely proportional to the conductivity of the sample, $\sigma = \frac{1}{\rho}$.
18. **Semiconductor.** It is a material which is, intrinsically, barely insulating in that the filled conduction band lies very close to the valence band. Semiconductors can be deliberately modified through patterned doping to produce complex, compact, and reliable electronic devices.

Frequently Asked Questions

Q1. **What is Hall Effect?**

Ans. The Hall Effect principle is named for physicist Edwin Hall. He discovered that when a conductor or semiconductor with current flowing in one direction was introduced perpendicular to a magnetic field a voltage could be measured at right angles to the current path.

Q2. **What do you mean by a hole?**

Ans. A hole is an electric charge carrier with a positive charge, equal in magnitude but opposite in polarity to the charge on the electron.

Q3. **Define Hall coefficient.**

Ans. The quotient of the potential difference per unit width of metal strip in the Hall Effect divided by the product of the magnetic intensity and the longitudinal current density.

Q4. **Give practical and absolute units of Hall coefficient.**

Ans The units of R_H are usually expressed as m^3/C, or Ω· cm /G, or other variants.

Q5. **On which factors does Hall voltage polarity depends?**

Ans. Hall voltage polarity is dependent upon both the polarity of the magnetic field and the direction of current through the conductor.

Q6. **What is an electromagnet?**

Ans. An electromagnet is a magnet that runs on electricity. Unlike a permanent magnet, the strength of an electromagnet can easily be changed by changing the amount of electric current that flows through it. The poles of an electromagnet can even be reversed by reversing the flow of electricity.

Q7. **What is current probe?**

Ans. A current probe is a device that can measure amperage without breaking a circuit. Current probes can be self contained devices, or they may be designed to work in conjunction with a multimeter.

Q8. **What is Hall voltage?**

Ans. The Hall Voltage is the potential created across a current-carrying metal-strip when the strip is placed in a magnetic field perpendicular to the current flow in the strip.

Q9. **What is a semiconductor?**

Ans. A semiconductor is a material which has electrical conductivity to a degree between that of a metal (such as copper) and that of an insulator (such as glass).

Q10. **Define Electric field.**

Ans. An electric field is a field around charged particles and changing magnetic fields which exerts a force on charges within the field.

Q11. **Define Magnetic field.**

Ans. A condition found in the region around a magnet or an electric current, characterized by the existence of a detectable magnetic force at every point in the region and by the existence of magnetic poles.

Warranty

- We warranty the product against all manufacturing defects for 12 months from The transportation charges shall be borne by the customer. The date of sale by us or through our dealers. Consumables like dry cell etc. are not covered under warranty.

- The warranty will become void, if
    - The product is not operated as per the instruction given in the learning material.
    - The agreed payment terms and other conditions of sale are not followed.
    - The customer resells the instrument to another party.
    - Any attempt is made to service and modify the instrument.
- The non-working of the product is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type, serial number of the product and date of purchase etc.
- The repair work will be carried out, provided the product is dispatched securely packed and insured.

List of Accessories

• Measurement Unit Nvis 622	1 No.
• Gauss & Tesla Meter Nvis 621	1 No.
• Constant Current Power Supply Nvis623	1 No.
• Electromagnet	1 No.
• Hall Effect Probe	1 No.
• In As Probe	1 No.
• Mains Cords	3 Nos.
• Probe Stand	1 No.
• RS-232 Cable	2 Nos.
• USB-Cable	1 No.

References

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