1. Photoelectric effect

Aim:

1. To understand the phenomenon Photoelectric effect as a whole.
2. To draw kinetic energy of photoelectrons as a function of frequency of incident radiation.
3. To determine the Planck's constant from kinetic energy versus frequency graph.
4. To plot a graph connecting photocurrent and applied potential.
5. To determine the stopping potential from the photocurrent versus applied potential graph.

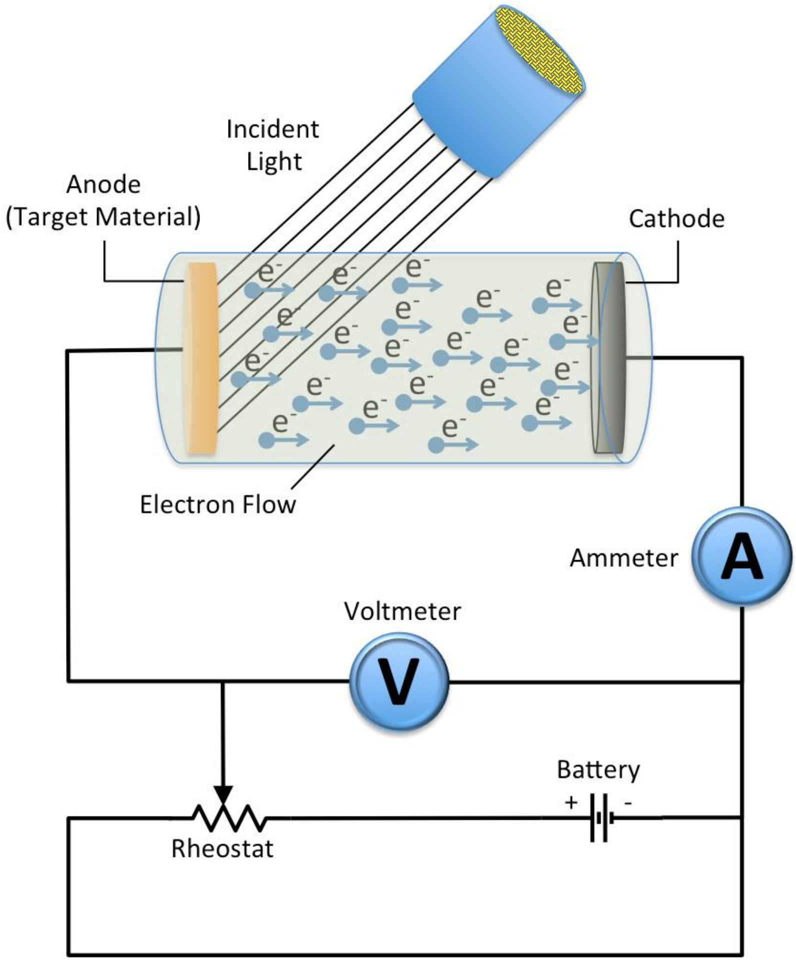
Theory:

During his experiments on electromagnetic radiation (to demonstrate light consists of e-m waves), Hertz noticed a spark between the two metallic balls when a high frequency radiation incident on it. This is called photoelectric effect. Photoelectric effect is the emission of electrons when electromagnetic radiations having sufficient frequency incident on certain metal surfaces. We call the emitted electrons as photoelectrons and the current they constitute as photocurrent. The phenomenon was first observed by Heinrich Hertz in 1880 and explained by Albert Einstein in 1905 using Max Planck's quantum theory of light. As the first experiment which demonstrated the quantum theory of energy levels, photoelectric effect experiment is of great historical importance.

The important observations on Photoelectric effect which demand quantum theory for its explanation are:

1. The Photoelectric effect is an instantaneous phenomenon. There is no time delay between the incidence of light and emission of photoelectrons.
2. The number of photoelectrons emitted is proportional to the intensity of incident light. Also, the energy of emitted photoelectrons is independent of the intensity of incident light.
3. The energy of emitted photoelectrons is directly proportional to the frequency of incident light.

The basic experimental set up which explains Photoelectric effect is as given below,



It has been observed that there must be a minimum energy needed for electrons to escape from a particular metal surface and is called work function 'W' for that metal. The work function can be expressed in terms of frequency as,

$$W = h\nu_0 \ldots\ldots\ldots\ldots\ldots (1)$$

Where h is the Planck's constant and ν_0 is the threshold frequency (minimum frequency for photoelectric effect).

The work function for some metals are listed in the table.

Metal	Work function (e V)
Platinum(Pt)	6.4
Silver(Ag)	4.7
Sodium(Na)	2.3
Potassium(K)	2.2
Cesium(Cs)	1.9

According to Einstein the Photoelectric effect should obey the equation,

$$h\nu = KE_{max} + W \ldots\ldots\ldots (2)$$

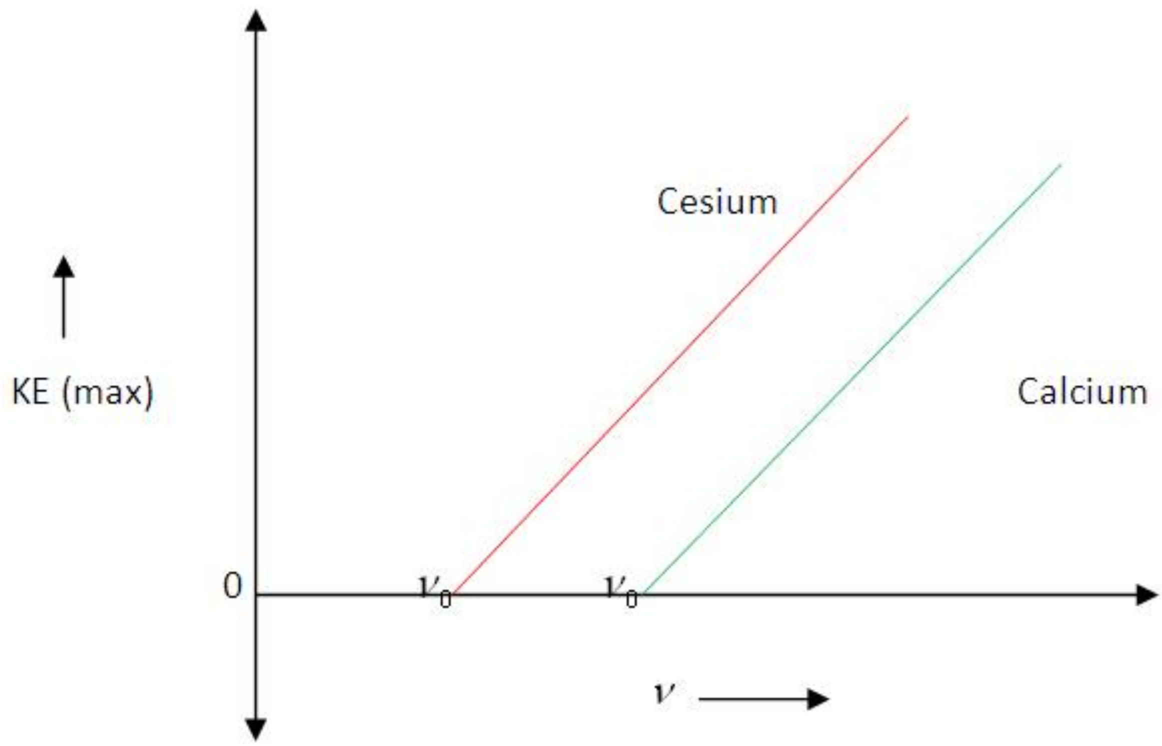
From the above expression,

$$KE_{max} = h\nu - h\nu_0$$

$$KE_{max} = h(\nu - \nu_0) ....(3)$$

Which says the graph connecting the maximum kinetic energy of photoelectrons 'KE_{max}' and frequency of incident radiation' ν 'will be a straight line with slope and Y-intercept $h\nu_0$ = workfunction.

Graph connecting 'KE_{max}' and frequency:



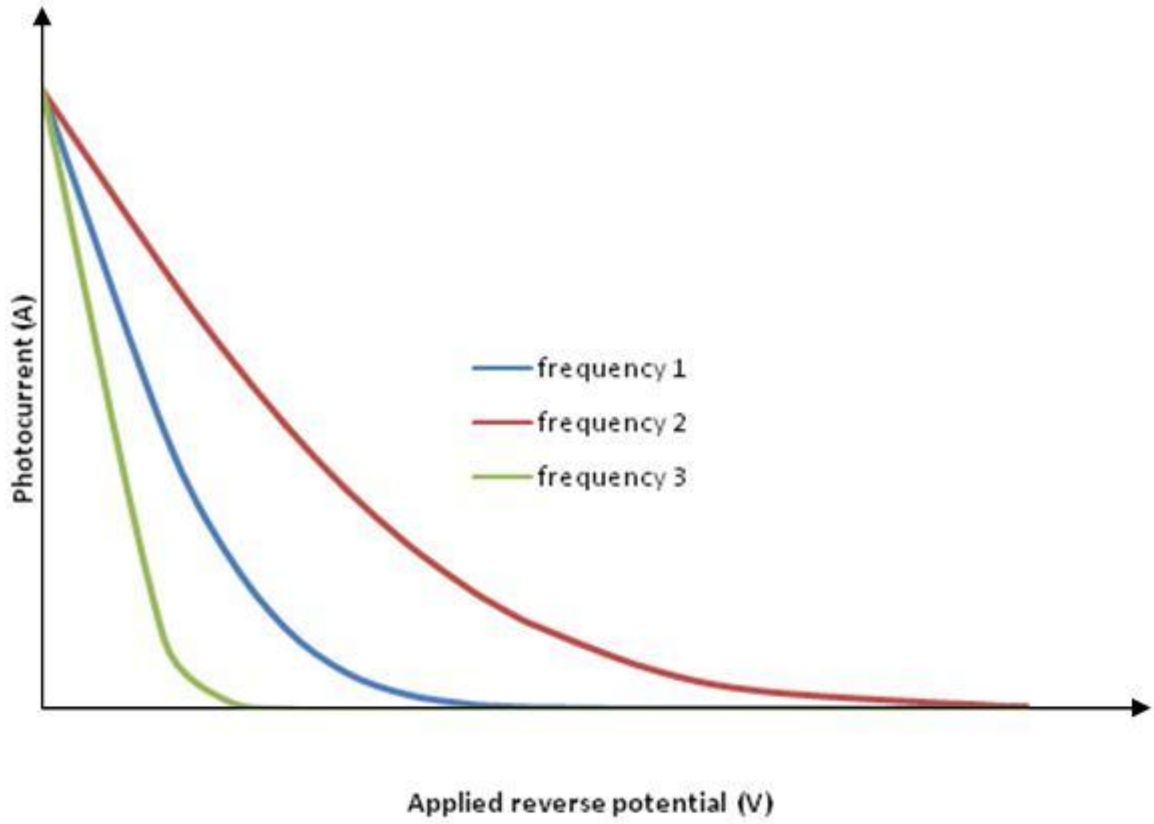
Maximum kinetic energy of photoelectrons versus frequency of incident radiation graph

Now, if we increase the reverse potential, the photocurrent gradually decreases and becomes zero at a particular reverse potential. This minimum applied reverse potential is called ***stopping potential V_0***. Hence the maximum kinetic energy of photoelectrons can be written as,

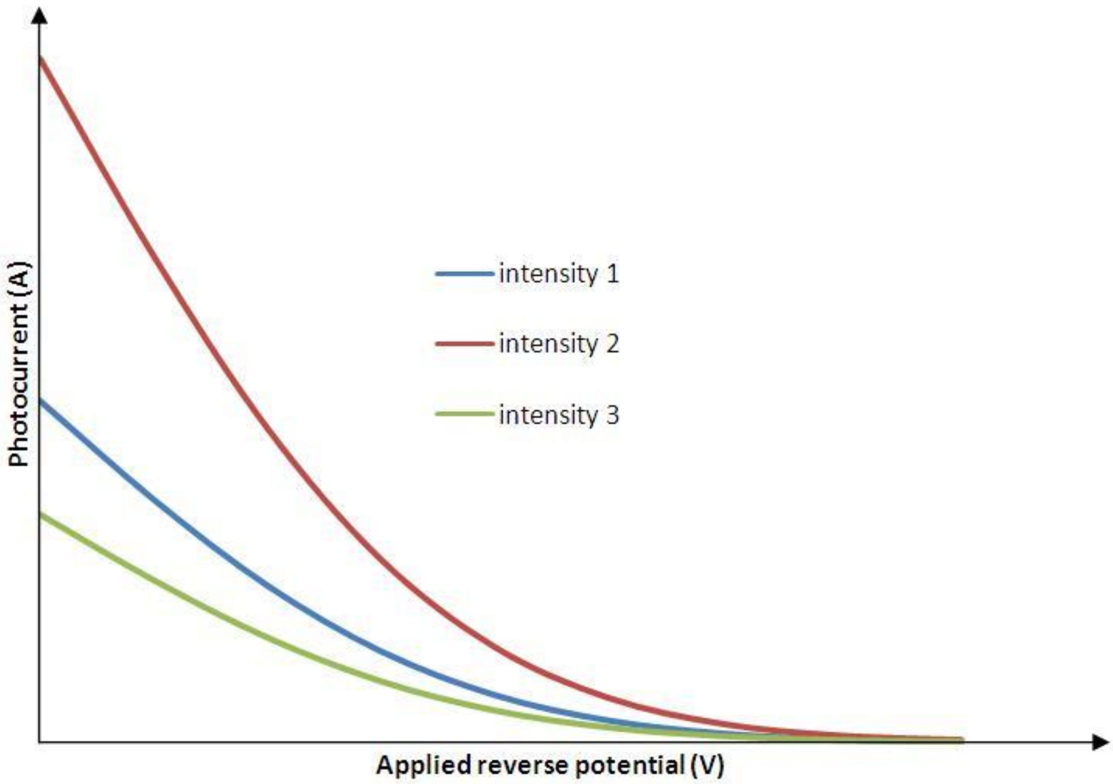
$$KE_{max} = eV_0 ....(4)$$

Graph connecting photocurrent and applied reverse potential :

For constant intensity and different frequencies



For constant frequency and different intensities



For performing the simulation:

1. Select the material for studying photoelectric effect.

2. Select area of the material,wave-length,intensity of incident light.

3. Switch on the light source.

4. Measure the reverse current for various reverse voltages.

5. Plot the current-voltage graph and determine the threshold voltage.

6. Repeat the experiment by varying the intensity for a particular wavelength of incident light.

7. Repeat the experiment by varying the wavelength for a particular intensity of the incident light
.

2. Plancks Constant

Aim

Determination of Planck's constant.

Apparatus

0-10 V power supply, a one way key, a rheostat, a digital milliammeter, a digital voltmeter, a 1 K resistor and different known wavelength LED's (Light-Emitting Diodes).

Theory

Planck's constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck's constant is that 'quanta' (small packets of energy) can be determined by frequency of radiation and Planck's constant. It describes the behavior of particle and waves at atomic level as well as the particle nature of light.

An LED is a two terminal semiconductor light source. In the unbiased condition a potential barrier is developed across the p-n junction of the LED. When we connect the LED to an external voltage in the forward biased direction, the height of potential barrier across the p-n junction is reduced. At a particular voltage the height of potential barrier becomes very low and the LED starts glowing, i.e., in the forward biased condition electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the **knee voltage** or the **threshold voltage**. Once the knee voltage is reached, the current may increase but the voltage does not change.

The light energy emitted during forward biasing is given as ,

$$E = \frac{hc}{\lambda} \qquad (1)$$

Where
c -velocity of light.
h -Planck's constant.
λ -wavelength of light.

If V is the forward voltage applied across the LED when it begins to emit light (the knee voltage), the energy given to electrons crossing the junction is,

$$E = eV \qquad (2)$$

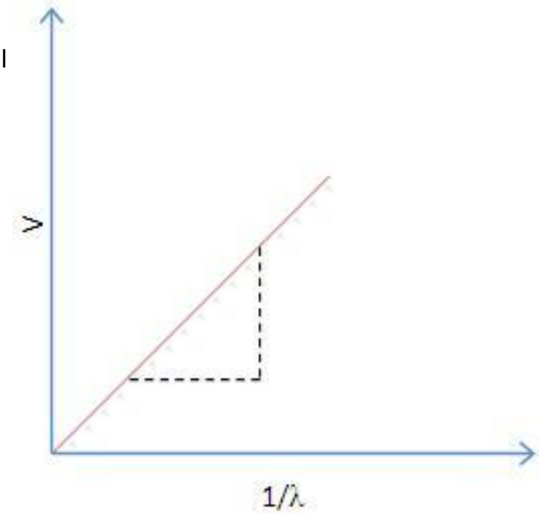
Equating (1) and (2), we get

$$eV = \frac{hc}{\lambda} \qquad (3)$$

The knee voltage V can be measured for LED's with different values of λ (wavelength of light).

$$V = \frac{hc}{e}\left(\frac{1}{\lambda}\right) \qquad (4)$$

Now from equation (4), we see that the slope s of a graph of V on the vertical axis vs. 1/λ on the horizontal axis is



$$s = \frac{hc}{e} \qquad (5)$$

To determine Planck's constant h, we take the slope s from our graph and calculate

$$h = \frac{e}{c}s$$

using the known value

$$\frac{e}{c} = 5.33 \ x \ 10^{-28}\frac{Cs}{m}$$

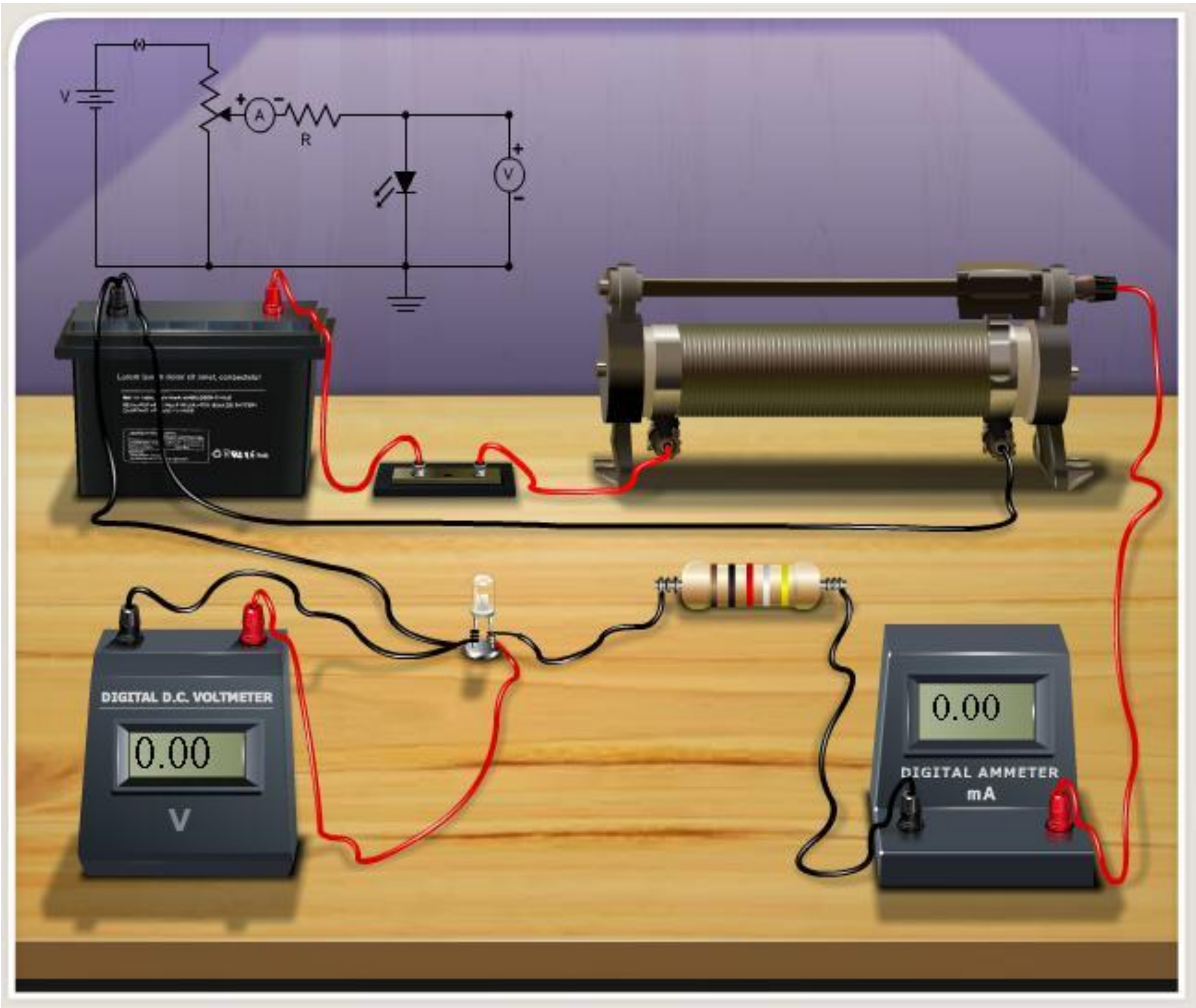
Alternatively, we can write equation (3) as

$$h = \frac{e}{c}\lambda V$$

calculate h for each LED, and take the average of our results.

Procedure for Simulation

Place the mouse pointer over the components and click to drag wire.



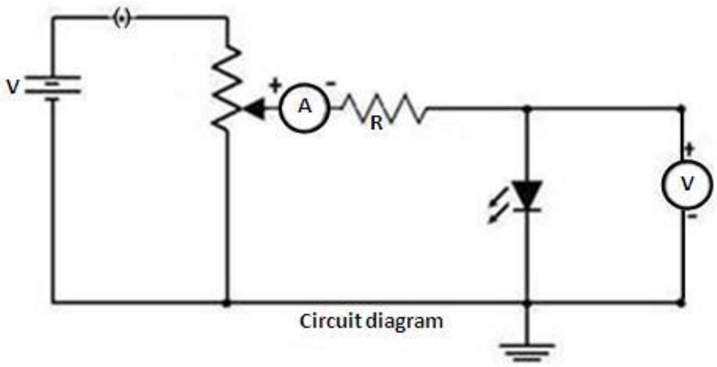
1. After the connections are completed, click on 'Insert Key' button.
2. Click on the combo box under 'Select LED' button.
3. Click on the 'Rheostat Value' to adjust the value of rheostat.

4. Corresponding voltage across the LED is measured using a voltmeter,which is the knee voltage.
5. Repeat, by changing the LED and note down the corresponding knee voltage.
6. Calculate 'h' using equation $$h = \frac{e\lambda V}{c}$$
7. The wave length of infrared LED is calculated by using equation, $$\lambda = \frac{hc}{eV}$$

Observations

Colour of LED	Wavelength (λ) nm	Knee voltage (V) volt	λxV	h = eλV/c

Procedure for Real lab



Circuit diagram

1. Connections are made as shown in circuit diagram.
2. Insert key to start the experiment.
3. Adjust the rheostat value till the LED starts glowing, or in the case of the IR diode, whose light is not visible, until the ammeter indicates that current has begun to increase.
4. Corresponding voltage across the LED is measured using a voltmeter,which is the knee voltage.
5. Repeat, by changing the LED and note down the corresponding knee voltage.
6. Using the formula given,find the value of the Planck's constant.

Results

Planck's constant = Js.
Wavelength of IR LED = nm.

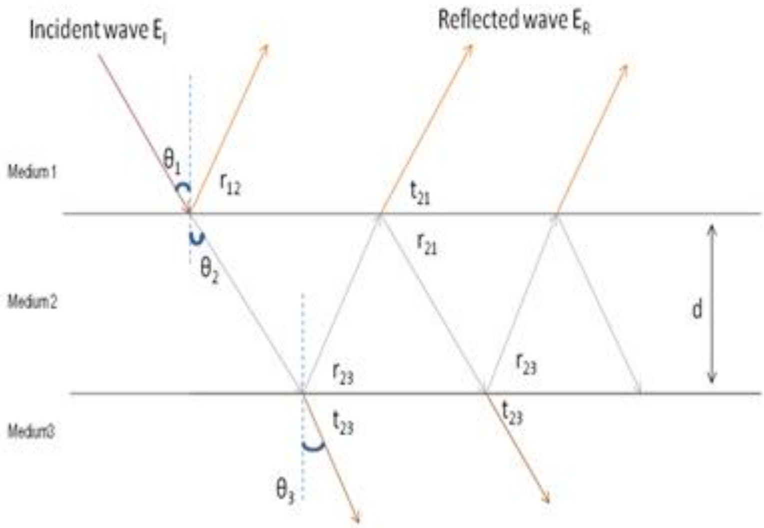
3. Newtons Rings

Aim:

1. To revise the concept of interference of light waves in general and thin-film interference in particular.
2. To set up and observe Newton's rings.
3. To determine the wavelength of the given source.

Thin film interference:

A film is said to be thin when its thickness is about the order of one wavelength of visible light which is taken to be 550 nm. When light is incident on such a film, a small portion gets reflected from the upper surface and a major portion is transmitted into the film. Again a small part of the transmitted component is reflected back into the film by the lower surface and the rest of it emerges out of the film. These reflected beams reunite to produce interference. Also the transmitted beams too interfere. This type of interference that takes place in thin films is called interference by division of amplitude.



Θ₁ angle of incidence at medium 1 to medium 2 boundary.
Θ₂ angle of refraction at medium 1 to medium 2 boundary.
Θ₃ angle of refraction at medium 2 to medium 3 boundary.
r_{12} reflected light from medium 1 to medium 2 boundary.
r_{23} reflected light from medium 2 to medium 1 boundary.
r_{21} reflected light from medium 2 to medium 3 boundary.
t_{21} transmitted light from medium 2 to medium 1 boundary.
t_{23} transmitted light from medium 2 to medium 3 boundary.
d thickness of the film.

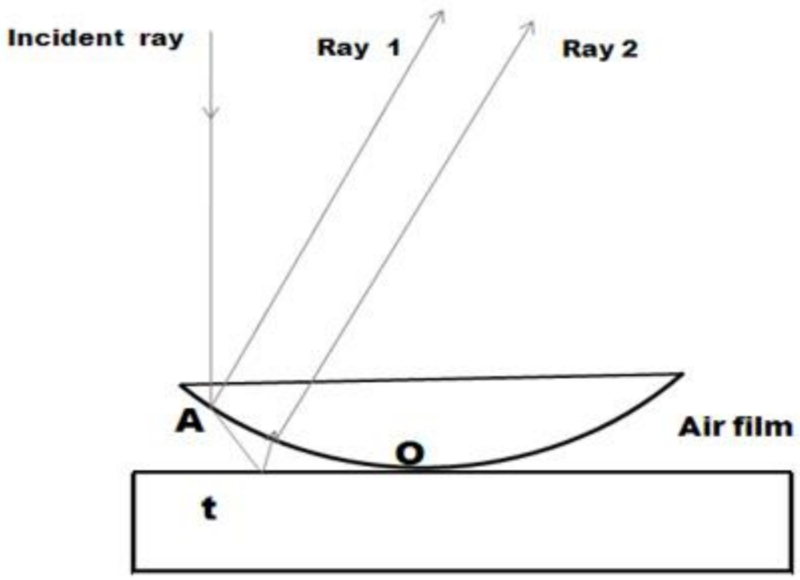
In the above figure the rays r_{12} and t_{21} interfere and results in a constructive or destructive interference depending on their path differences, given as,

$$2\mu_2 d cos r_{12} = (2m+1)\frac{\lambda}{2}$$ **constructive interference**

$$2\mu_2 d cos r_{12} = m\lambda$$ **destructive interference**

Where, $\mu_2 \rightarrow$ refractive index of the medium 2 and $m = 0, 1, 2, ... \rightarrow$ the order of interference. The transmitted light from t_{23} can also interfere and result in constructive or destructive interference.

Thin film interference with films of varying thickness (Newton's rings):



Rings are fringes of equal thickness. They are observed when light is reflected from a plano-convex lens of a long focal length placed in contact with a plane glass plate. A thin air film is formed between the plate and the lens. The thickness of the air film varies from zero at the point of contact to some value t. If the lens plate system is illuminated with monochromatic light falling on it normally, concentric bright and dark interference rings are observed in reflected light. These circular fringes were discovered by Newton and are called Newton's rings.

A ray AB incident normally on the system gets partially reflected at the bottom curved surface of the lens (Ray 1) and part of the transmitted ray is partially reflected (Ray 2) from the top surface of the plane glass plate. The rays 1 and 2 are derived from the same incident ray by division of amplitude and therefore are coherent. Ray 2 undergoes a phase change of p upon reflection since it is reflected from air-to-glass boundary.

The condition for constructive and destructive interferences are given as; for normal incidence **cos r = 1** and for air film μ **= 1.**

$$2t = (2m + 1)\frac{\lambda}{2}$$ **constructive interference**

$$2t = m\lambda$$ **destructive interference**

1. **Central dark spot:** At the point of contact of the lens with the glass plate the thickness of the air film is very small compared to the wavelength of light therefore the path difference introduced between the interfering waves is zero. Consequently, the interfering waves at the centre are opposite in phase and interfere destructively. Thus a dark spot is produced.

2. **Circular fringes with equal thickness:** Each maximum or minimum is a locus of constant film thickness. Since the locus of points having the same thickness fall on a circle having its centre at

the point of contact, the fringes are circular.

3. **Fringes are localized:** Though the system is illuminated with a parallel beam of light, the reflected rays are not parallel. They interfere nearer to the top surface of the air film and appear to diverge from there when viewed from the top. The fringes are seen near the upper surface of the film and hence are said to be localized in the film.

4. **Radii of the mth dark rings:** $r_m = \sqrt{m\lambda R}$.

5. **Radii of the mth bright ring:** $r_m = \sqrt{(2m+1)R\frac{\lambda}{2}}$.

6. The radius of a dark ring is proportional to the radius of curvature of the lens by the relation, $r_m \; \alpha \sqrt{R}$.

7. Rings get closer as the order increases (m increases) since the diameter does not increase in the same proportion.

8. In transmitted light the ring system is exactly complementary to the reflected ring system so that the centre spot is bright.

9. Under white light we get coloured fringes.

10. The wavelength of monochromatic light can be determined as, $\lambda = \frac{D^2_{m+p} - D^2_m}{4\,p\,R}$.
    Where, D_{m+p} is the diameter of the $(m+p)^{th}$ dark ring and D_m is the diameter of the m^{th} dark ring.

Performing Real Lab

After experimental arrangement, the glass plate is inclined at an angle 45° to the horizontal.This glass plate reflects light from the source vertically downloads and falls normally on the convex lens. Newton's rings are seen using a long focus microscope, focussed on the air fil. The cross-wire of the microscope is made tangential to the 20th ring on the left side of the centre. The readings of the main scale and vernier scale of the microscope are noted. The cross wire is adjusted to be tangential to the 18th, 16th, 14th, etc on the left and 2nd, 4th, 6th, etc on the right and readings are taken each time. From this the diameter of the ring is found out which is the difference between the readings on the left and right sides. The square of the diameter and hence Dn^2 and D^2n+m are found out. Then wavelength is calulated using equation.

Performing the simulation:

The simulation virtualizes the Newton's rings experiment. The user can view the effect of Newton's rings formed when the medium changes. Select any one type of medium. Different ring pattern can be seen by changing the radius of curvature of the lens and wavelength of light source.
.

Components:

Start button, Light source, Filter, Microscope, Lens, Medium and Glass plate.

Help:

Variable region:

1. Choose Medium Combo box helps you to choose the type of medium that the simulation have to perform.
2. Radius Slider helps to change the radius of curvature of lens.
3. The wavelength slider helps to change the wavelength of light used.

Measurement region:

1. The start button will help to play the simulation.
2. The variation in the rings can be seen when the medium,wavelength of light or the radius of the lens changes.

Procedure:

1. Click on the "light on" button.
2. Select the lens of desirable radius.
3. Adjust the microscope position to view the Newton rings.
4. Focus the microscope to view the rings clearly.
5. Fix the cross-wire on 20^{th} ring either from right or left of the centre dark ring and take the readings .
6. Move the crosswire and take the reading of 18^{th},16^{th}..........2^{nd} ring.
7. You have to take the reading of rings on either side of the centre dark ring.
8. Enter the readings in the tabular column.
9. Calculate the wavelength of the source by using the given formula.

Observations:

To find Least Count

One main scale division = ... cm

Number of divisions on Vernier = ...

L.C = One main scale division/ Number of division on vernier=................................

Order of ring	Microscopic Reading (cm)		Diameter D(cm)	$D^2(cm^2)$	$D^2_{m+p} - D^2_m$ (cm^2)
	Left	Right			

Calculation:

Mean value of D^2_{m+p} - D^2_m =.......cm^2

Wavelength of light λ = $(D^2_{m+p} - D^2_m)/4pR$

=.............................nm

Result:

Wavelength of light from the given source is found to be = ...nm

4. Halls Effect

Aim:

1. To determine the Hall voltage developed across the sample material.
2. To calculate the Hall coefficient and the carrier concentration of the sample material.

Apparatus:

Two solenoids, Constant current supply, Four probe, Digital gauss meter, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

Theory:

If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

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

$$J_x = I/wt \qquad (1)$$

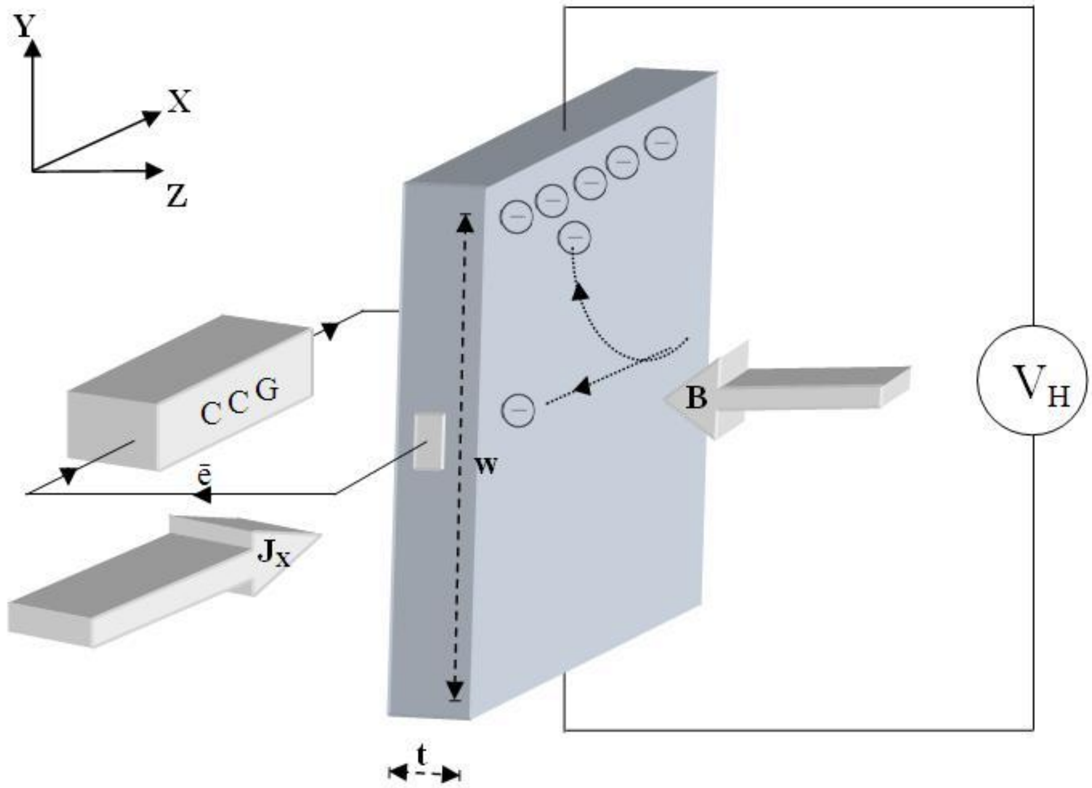


Fig.1 Schematic representation of Hall Effect in a conductor.
CCG – Constant Current Generator, J_X – current density
ē – electron, ***B*** – applied magnetic field
t – thickness, ***w*** – width
V_H – Hall voltage

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

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0,the voltage difference will be zero.

We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz force, $F_m = q(vxB)$ causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

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

$$eE = evB \qquad (2)$$

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers.
And the current 'I' can be expressed as,

$$I = neAv \qquad (3)$$

Where 'n' is the number density of electrons in the conductor of length l ,breadth 'w' and thickness 't'.
Using (1) and (2) the Hall voltage V_H can be written as,

$$V_H = Ew = vBw = \frac{IB}{net}$$

$$V_H = R_H \frac{IB}{t} \qquad (4)$$

by rearranging eq(4) we get

$$R_H = \frac{V_H * t}{I * B} \qquad (5)$$

Where R_H is called the Hall coefficient.

$$R_H = 1/ne \qquad (6)$$

Procedure:

Controls

Combo box

Select procedure: This is used to select the part of the experiment to perform.

1) Magnetic field Vs Current.
2) Hall effect setup.

Select Material: This slider activate only if Hall Effect setup is selected. And this is used to select the material for finding Hall coefficient and carrier concentration.

Button

Insert Probe/ Remove Probe: This button used to insert/remove the probe in between the solenoid.

Show Voltage/ Current: This will activate only if Hall Effect setup selected and it used to display the Hall voltage/ current in the digital meter.

Reset: This button is used to repeat the experiment.

Slider

Current : This slider used to vary the current flowing through the Solenoid.

Hall Current: This slider used to change the hall current
Thickness: This slider used to change the thickness of the material selected.

Procedure for doing the simulation:

To measure the magnetic field generated in the solenoid

- Select **Magnetic field Vs Current from** the procedure combo-box.
- Click **Insert Probe** button
- Placing the probe in between the solenoid by clicking the wooden stand in the simulator.
- Using Current slider, varying the current through the solenoid and corresponding magnetic field is to be noted from Gauss meter.

Trial No:	Current through solenoid	Magnetic field generated
1		
2		
3		
4		

Table(1**)**

Hall Effect apparatus

- Select **Hall Effect Setup** from the **Select the procedure** combo box
- Click **Insert Hall Probe** button
- Placing the probe in between the solenoid by clicking the wooden stand in the simulator.
- Set "**current slider**" value to minimum.
- Select the material from "Select Material" combo-box.
- Select the Thickness of the material using the slider **Thickness**.
- Vary the Hall current using the sllider **Hall current**.
- Note down the corresponding Hall voltage by clicking "show voltage" button.
- Then calculate Hall coefficient and carrier concentration of that material using the equation

$$R_H=V_Ht/(I*B)$$

Where R_H is the Hall coefficient

$$R_H=1/ne$$

And n is the carrier concentration

- Repeat the experiment with different magnetic file.

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

Procedure for doing real lab

- Connect 'Constant current source' to the solenoids.
- Four probe is connected to the Gauss meter and placed at the middle of the two solenoids.
- Switch ON the Gauss meter and Constant current source.
- Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings.
- Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
- Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator and connect red wires to milli voltmeter in the Hall Effect apparatus
- Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids.
- Switch ON the constant current source and CCG.
- Carefully increase the current I from CCG and measure the corresponding Hall voltage V_H. Repeat this step for different magnetic field B.
- Thickness t of the sample is measured using screw gauge.
- Hence calculate the Hall coefficient R_H using the equation 5.
- Then calculate the carrier concentration n. using equation 6.

Result

Hall coefficient of the material = ...
Carrier concentration of the material =......................... m^{-3}

5. Resistivity by 4 Probes

rocedure

elf Evaluation

imulator

ssignment

eference

eedback

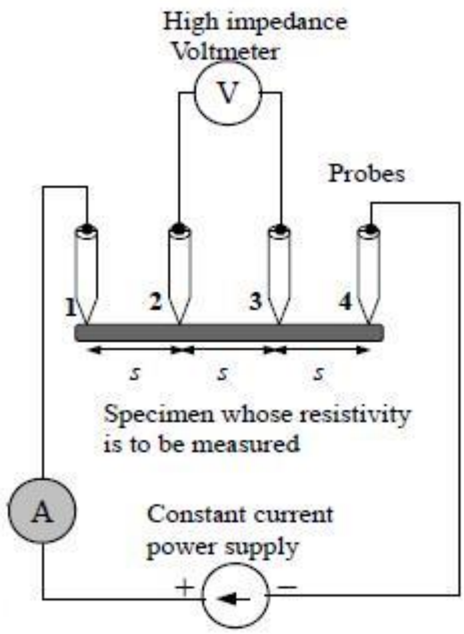
AIM

To determine the resistivity of semiconductors by Four probe Method.

APPARATUS

The experimental set up consists of probe arrangement, sample , oven 0-200°C, constant current generator , oven power supply and digital panel meter(measuring voltage and current).

Four probe apparatus is one of the standard and most widely used apparatus for the measurement of resistivity of semiconductors.
This method is employed when the sample is in the form of a thin wafer, such as a thin semiconductor material deposited on a substrate. The sample is millimeter in size and having a thickness w. It consists of four probe arranged linearly in a straight line at equal distance S from each other. A constant current is passed through the two probes and the potential drop V across the middle two probes is measured. An oven is provided with a heater to heat the sample so that behavior of the sample is studied with increase in temperature.



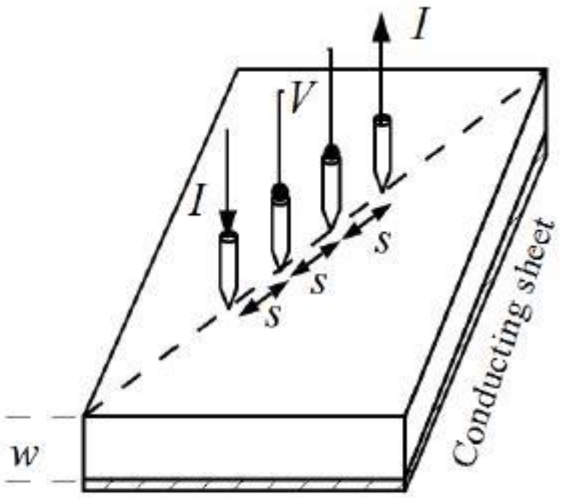


Fig:1 Fig:2

The figure shows the arrangements of four probes that measure voltage (V) and supply current (A) to the surface of the crystal.

THEORY

At a constant temperature, the resistance, R of a conductor is proportional to its length L and inversely proportional to its area of cross section A.

$$R = \rho \frac{L}{A} \qquad (1)$$

Where ρ is the resistivity of the conductor and its unit is ohmmeter.

A semiconductor has electrical conductivity intermediate in magnitude between that of a conductor and insulator. Semiconductor differs from metals in their characteristic property of decreasing electrical resistivity with increasing temperature.

According to band theory, the energy levels of semiconductors can be grouped into two bands, valence band and the conduction band. In the presence of an external electric field it is electrons in the valence band that can move freely, thereby responsible for the electrical conductivity of semiconductors. In case of intrinsic semiconductors, the Fermi level lies in between the conduction band minimum and valence band maximum. Since conduction band lies above the Fermi level at 0K, when no thermal excitations are available, the conduction band remains unoccupied. So conduction is not possible at 0K, and resistance is infinite. As temperature increases, the occupancy of conduction band goes up, thereby resulting in decrease of electrical resistivity of semiconductor.

Resistivity of semiconductor by four probe method

1. The resistivity of material is uniform in the area of measurement.
2. If there is a minority carrier injection into the semiconductor by the current- carrying electrodes most of the carriers recombine near electrodes so that their effect on conductivity is negligible.
3. The surface on which the probes rest is flat with no surface leakage.
4. The four probes used for resistivity measurement contact surface at points that lie in a straight line.
5. The diameter of the contact between metallic probes and the semiconductor should be small compared to the distance between the probes.
6. The boundary between the current carrying electrodes and the bulk material is hemispherical and small in diameter.
7. The surface of semiconductor material may be either conducting and non-conducting. A conducting boundary is one on which material of much lower resistivity than semiconductor has been plated. A non-conducting boundary is produced when the surface of the semiconductor is in contact with insulator.

Fig: 2 show the resistivity probes on a die of material. If the side boundaries are adequately far from the probes, the die may be considered to be identical to a slice. For this case of a slice of thickness w and the resistivity is computed as

$$\rho = \frac{\rho_0}{f(\frac{w}{S})} \qquad (2)$$

The function, f(w/S) is a divisor for computing resistivity which depends on the value of w and S We assume that the size of the metal tip is infinitesimal and sample thickness is greater than the distance between the probes,

$$\rho_0 = \frac{V}{I} \times 2\pi S \qquad (3)$$

Where V – the potential difference between inner probes in volts.

I – Current through the outer pair of probes in ampere.

S – Spacing between the probes in meter.

Temperature dependence of resistivity of semiconductor

Total electrical conductivity of a semiconductor is the sum of the conductivities of the valence band and conduction band carriers. Resistivity is the reciprocal of conductivity and its temperature dependence is given by

$$\rho = A \exp \frac{E_g}{2KT} \qquad (4)$$

Where Eg – band gap of the material
T – Temperature in kelvin
K – Boltzmann constant, K – 8.6x10-5 eV/K
The resistivity of a semiconductor rises exponentially on decreasing the temperature.

Applications

1. Remote sensing areas
2. Resistance thermometers
3. Induction hardening process
4. Accurate geometry factor estimation
5. Characterization of fuel cells bipolar plates

Procedure for Simulation

Combo Box and Sliders

- **Select Material** - This is used to select semiconductor material for doing the simulator.

- **Range of Current** - One can choose the range of current for the current source.

- **Current' Slider** - It ranges from 1mA to 200mA. (Note:The divisions in the slider is fixed as 100). If 20mA current is selected in the combo box, the slider value will range from 0mA to 20mA, with an interval of 0.2mA and if the value is 200mA in the combo box, slider value changes from 0mA to 200mA with an interval of 2mA.

- **Range of oven** - This combo box is used to fix the temepratura to a particular range.

- **Oven**- Oven is used to vary the temeprature upto 200^0 C.
  Set Button – It is used to fix the temperature in the oven.
  Run Button – After setting the temperature, using run button we can start heating the oven.
  Wait Button – It is used to stop heating the oven at a particular temperature.
  Measure Button- It is used to display the present temperature of the oven.

- **Select Range Combo Box** – Options are X1 and X10.

- **Temperature slider** - it ranges from 27^0 C to 200^0 C. active only by clicking the Set button and become inactive after clicking Run button. If X1 is in combo box, the slider value ranges from 27^0 C to 99^0 C and If the value is X10 in combo box, slider value changes from 2.7 0 C to 200 C.

- **Voltmeter Combo Box** - Options are 1 mV, 10 mV, 100 mV, 1 V, 10 V. One can select it for getting output in a particular range.

Procedure

1. Select the semiconductor material from the combo box.

2. Select the source current from the slider. Restrict the slider based on the range of current.

3. Select the Range of oven from the combo box.

4. Set the temperature from the slider.

5. Click on the Run Button to start heating the oven in a particular interval, from the default 25^{0}C to the temperature that we set already Click on the Wait button to stop heating.

6. Click on the Set button to display the temperature that we set in the oven.

7. Click on the Measure button to display the present temperature in the oven.

8. Select the range of voltmeter from the combo box.

9. Measure the Voltage using Voltmeter.

10.Calculate the Resistivity of semiconductor in eV for the given temperature using equation (2) and (3).

11. A Graph is plotted with Temperature along x-axis and resistivity of semiconductor along y-axis.

Procedure for Real Lab

In real lab, four probes are placed on the sample as shown in Fig:1. Connections are made as shown in the simulator. A constant current is passed through the outer probes by connecting it to the constant current source of the set up. The current is set to 8mA. The voltage developed across the middle two probes is measured using a digital milli-voltmeter. The trial is repeated by placing the four probe arrangement inside the oven. The oven is connected to the heater supply of the set up. For different temperatures, upto 150^{0}C, the voltage developed is noted and tabulated.
The distance between the probes(S) and the thickness of the crystal (W) are measured. The values of (W/S) are calculated and the value of the function f(W/S) ia taken from the standard table. Using equation (2) and (3), calculate ρ for various temperatures.

Observations and Calculations

Temperature,T (K)	Voltage,V(mV)	Current, I(mA)	Resistivity ,ρ(Ohm cm)

Resistivity can be calculated by using the equation given below.
Here we take,
Distance between the probes, S as0.2cm and
Thickness of the sample,w as 0.05cm.
From standard table f(w/S) = 5.89

$$\rho = \frac{\rho_0}{f(\frac{w}{s})}$$

= .... Ohm cm

$$\rho_0 = \frac{V}{I} \times 2\pi S$$

= .... Ohm cm

Result

The resistivity of the given semiconductor by Four probe Method = ...Ohm cm

6. Energy Band Gap

Aim

To Determine Energy Band Gap of Semiconductor

Theory

About the Experiment:

In the case of insulators, the region between highest level of completely filled valence band and the lowest level of allowed conduction band is very wide. This is called energy gap, denoted by Eg and is about 3 eV to 7 eV in case of insulators. In case of semiconductors, this energy gap is quite small. For example, in case of germanium, Eg =0.7 eV and in case of silicon Eg =1.1 eV. In semi conductors at low temperatures, there are few charges carrriers to move so conductivity is quite low. At higher temperatures, the donor or acceptor levels come in to action and provide charge carriers and hence the conduction increases. In addition to the dependence of the electrical conductivity on the number of free charges, it also depends on their mobility. However, mobility of the charge carriers somewhat decrease with increasing temperature but on the average the conductivity of the semiconductors rises with increasing temperature. To determine the energy gap of a semi-conducting material, we study the variation of its conductance with temperature. In reverse bias, the currents flowing through the junction are quite small and internal heating of the junction does not take place.

In the reverse bias, the saturated value of the reverse current for a PN junction diode is given by,

Is =A.T3/2 e -Eg/KT _ _ _ _ _(1)

Where,

A= constant term

Is = saturation current in micro ampere

T = temperature of junction diode in Kelvin

Eg = band gap in eV

K = Boltzman constant in eV per Kelvin

For small changes in temperature where log T can be treated as constant relation (1) can be written as

log10Is = constant – 5.04 Eg. 103 /T_ _ _ _ (2)

Graph between 103 /T as abscissa and log10Is as ordinate will be a straight line having a slope = 5.04Eg

Hence band gap

Eg = slope of the line / 5.04

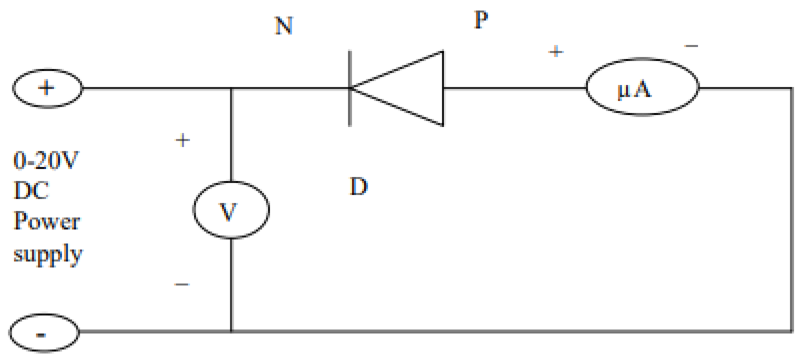


Figure 1

7. Numerical aperture of optical fibre

Aim:

To find the numerical aperture of a given optic fibre and hence to find its acceptance angle.

What is optic fibre?

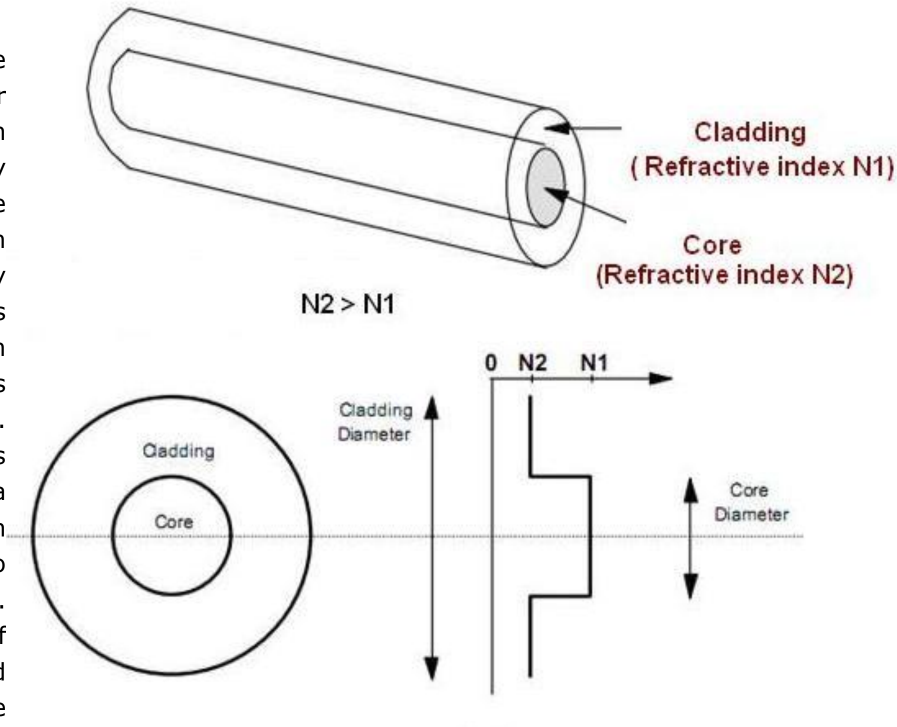


Fig (1)

Optical fibers are fine transparent glass or plastic fibers which can propagate light. They work under the principle of total internal reflection from diametrically opposite walls. In this way light can be taken anywhere because fibers have enough flexibility. This property makes them suitable for data communication, design of fine endoscopes, micro sized microscopes etc. An optic fiber consists of a core that is surrounded by a cladding which are normally made of silica glass or plastic. The core transmits an optical signal while the cladding guides the light within the core. Since light is guided through the fiber it is sometimes called an optical wave guide. The basic construction of an optic fiber is shown in figure (1).

In order to understand the propagation of light through an optical fibre, consider the figure (2). Consider a light ray (i) entering the core at a point A , travelling through the core until it reaches the core cladding boundary at point B. As long as the light ray intersects the core-cladding boundary at a small angles, the ray will be reflected back in to the core to travel on to point C where the process of reflection is repeated .ie., total internal reflection takes place. Total internal reflection occurs only when the angle of incidence is greater than the critical angle. If a ray enters an optic fiber at a steep angle(ii), when this ray intersects the core-cladding boundary, the angle of intersection is too large. So, reflection back in to the core does not take place and the light ray is lost in the cladding. This means that to be guided through an optic fibre, a light ray must enter the core with an angle less than a particular angle called the acceptance angle of the fibre. A ray which enters the fiber with an angle greater than the acceptance angle will be lost in the cladding.

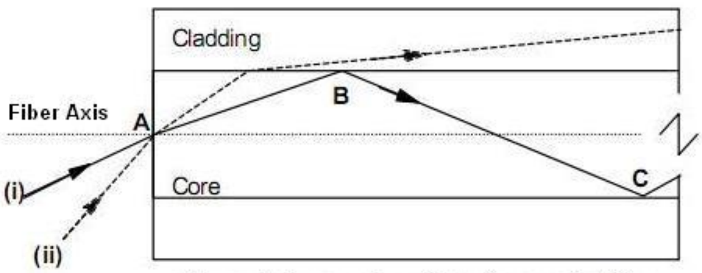


Figure 2 Propagation of light in an optical fibre

Consider an optical fibre having a core of refractive index n_1 and cladding of refractive index n_2. let the incident light makes an angle i with the core axis as shown in figure (3). Then the light gets refracted at an angle θ and fall on the core-cladding interface at an angle where,

$$\theta' = (90 - \theta) \quad \text{----------------------} \quad (1)$$

By Snell's law at the point of entrance of light in to the optical fiber we get,

$$n_0 \sin i = n_1 \sin \theta \quad \text{--------------------} (2)$$

Where n_0 is refractive index of medium outside the fiber. For air $n_0 = 1$.

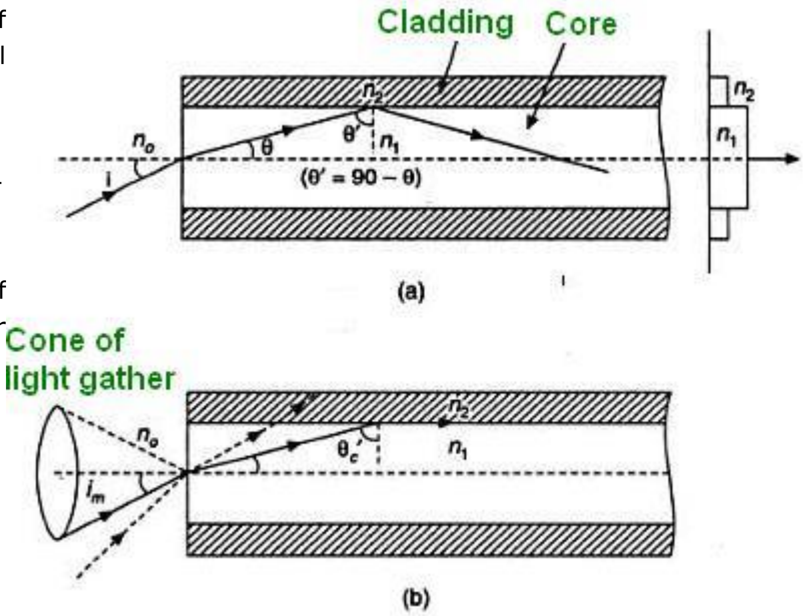


Figure 3.

When light travels from core to cladding it moves from denser to rarer medium and so it may be totally reflected back to the core medium if θ' exceeds the critical angle θ'_c. The critical angle is that angle of incidence in denser medium (n1) for which angle of refraction become 90°. Using Snell's laws at core cladding interface,

$$n_1 \sin \theta'_c = n_2 \sin 90$$

or

$$Sin\, \theta'_c = \frac{n_2}{n_1} \quad \text{-----------------------} (3)$$

Therefore, for light to be propagated within the core of optical fiber as guided wave, the angle of incidence at core-cladding interface should be greater than θ'_c. As i increases, θ increases and so θ' decreases. Therefore, there is maximum value of angle of incidence beyond which, it does not propagate rather it is refracted in to cladding medium (fig: 3(b)). This maximum value of i say i_m is called maximum angle of acceptance and $n_0 \sin i_m$ is termed as the numerical aperture (NA).
From equation(2),

$$NA = n_0 \sin i_m = n_1 \sin \theta$$

$$= n_1 \sin(90 - \theta_c)$$

$$Or\ NA = n_1\, Cos\, \theta'_c$$

$$= n_1 \sqrt{1 - Sin^2 \theta'_c}$$

From equation (2)

$$\sin \theta'_c = \frac{n_2}{n_1}$$

Therefore,

$$NA = n1\sqrt{1 - \frac{n_2^{\,2}}{n_1^2}}$$

$$NA = \sqrt{n_1^{\,2} - n_2^{\,2}}$$

The significance of NA is that light entering in the cone of semi vertical angle i_m only propagate through the fibre. The higher the value of i_m or NA more is the light collected for propagation in the fibre. Numerical aperture is thus considered as a light gathering capacity of an optical fibre.
Numerical Aperture is defined as the Sine of half of the angle of fibre's light acceptance cone. i.e. NA= Sin θ_a where θ_a, is called acceptance cone angle.

Let the spot size of the beam at a distance d (distance between the fiber end and detector) as the radius of the spot(r). Then,

$$\sin\theta = \frac{r}{\sqrt{r^2 + d^2}} \quad \text{------------------------- (4)}$$

Procedure for simulator Controls

Start button: To start the experiment.
Switch on: To switch on the Laser.
Select Fiber: To select the type of fiber used.
Select Laser: To select a different laser source.
Detector distance (Z): Use the slider to vary the distance between the source and detector. (ie toward the fiber or away from the fiber.
Detector distance(x): Use the slider to change the detector distance i.e towards left or right w.r.t the fiber.
Show Graph: To Displays the graph.
Reset: To resets the experimental arrangement.

Preliminary Adjustment

- Drag and drop each apparatus in to the optical table as shown in the figure below.

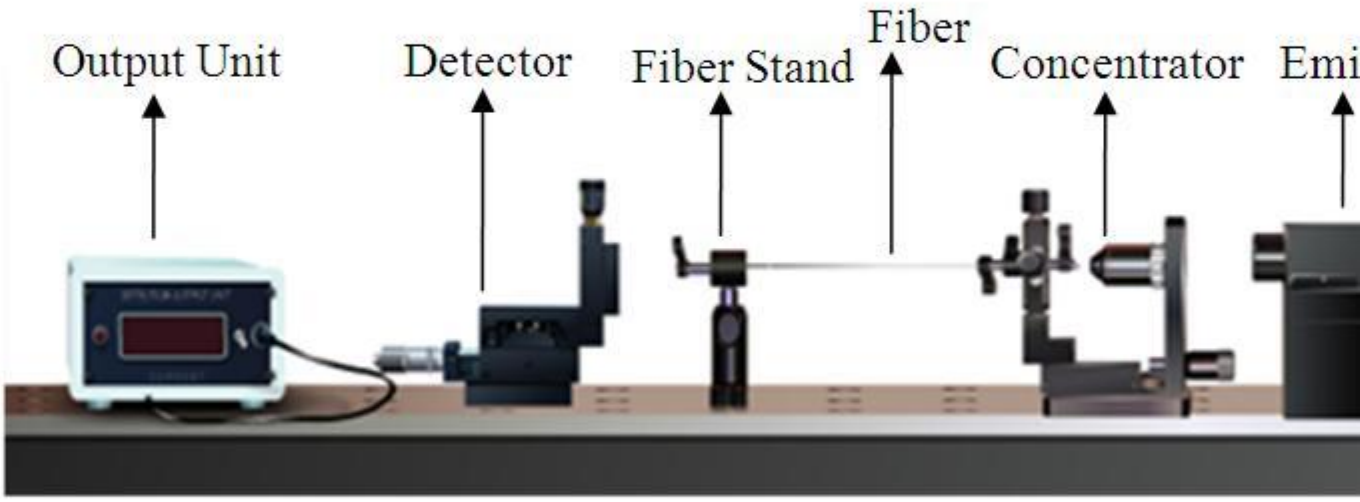


Fig (4)

- Then Click “Start” button.
- Switch On (now you can see a spot in the middle of the detector)
- After that select the Fiber and Laser for performing the experiment from the control options.

To perform the experiment

- Set the detector distance Z (say 4mm). We referred the distance as “d” in our calculation.
- Vary the detector distance X by an order of 0.5mm, using the screw gauge (use up and down arrow on the screw gauge to rotate it).
- Measure the detector reading from output unit and tabulate it.
- Plot the graph between X in x-axis and output reading in y-axis. See figure 5.
- Find the radius of the spot r, which is corresponding to Imax/2.71 (See the figure 5).

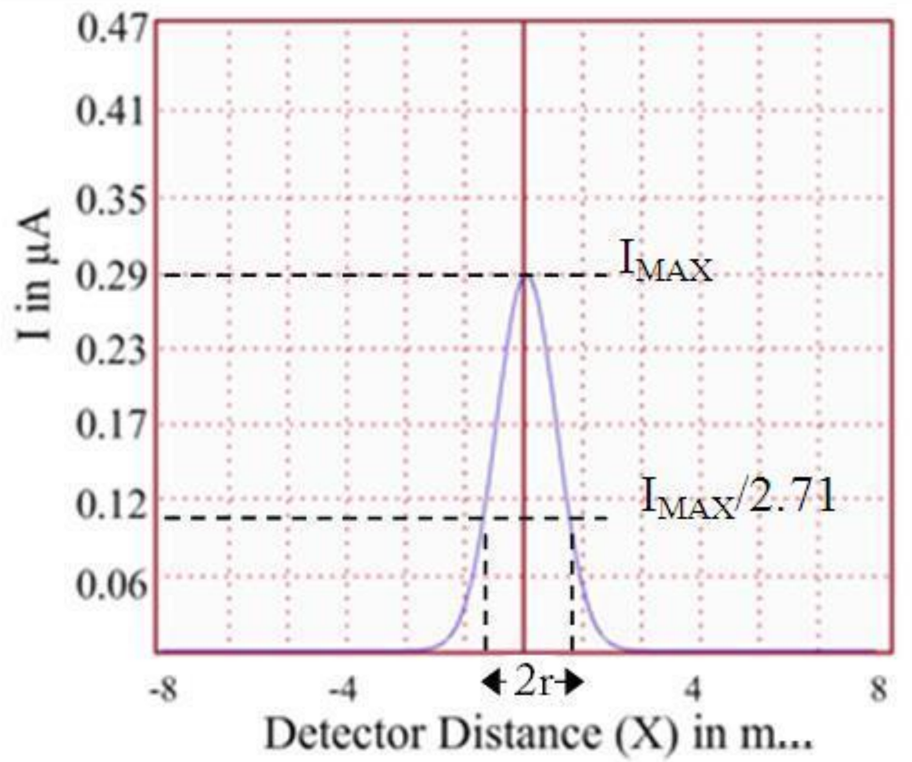


Fig (5)

- Then find the numerical aperture of the optic fiber using the equation (4).

Observation column

SL No.	Screw gauge reading		Distance (X) mm	I μA
	H.S.R	P.S.R		

Calculations

Distance between the fiber and the detector, d = ... m
Radius of the spot, r =........................... m

Numerical Aperture of the optic fiber, sin(θ) = $\frac{r}{\sqrt{r^2+d^2}}$ = ...

Acceptance angle, θ= $sin^{-1}\left(\frac{r}{\sqrt{r^2+d^2}}\right)$ = ...

Result

Numerical aperture of the optic fiber is = ...
Angle of acceptance = ...

8. Van De Graaff

Theory:

The American physicist, Dr. Robert Jemison Van de Graaff invented the Van de Graaff generator in 1931. The device has the ability to produce extremely high voltages - as high as 20 million volts. Van de Graaff invented the generator to supply the high energy needed for early particle accelerators. These accelerators are known as atom smashers because they accelerates the sub atomic particles to very high speeds and then "smash" them in to the target atoms. The resulting collision creates other sub atomic particles and high energy radiations such as X-rays. The ability to create these high energy collisions is the foundation of particle and nuclear physics.

Working of the generator is based on two principles:

1. Discharging action of sharp points, ie., electric discharge takes place in air or gases readily, at pointed conductors.
2. If the charged conductor is brought in to internal contact with a hollow conductor, all of its charge transfers to the surface of the hollow conductor no matter how high the potential of the latter may be.

Theory behind construction:

If we have a large conducting spherical shell of radius 'R' on which we place a charge Q, it spreads itself uniformly all over the sphere. The field outside the sphere is just that of a point charge Q at the centre, while the field inside the sphere vanishes. So the potential outside is that of point charge and inside it is constant.

The potential inside the conducting sphere = $\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

Now suppose that we introduce a small sphere of radius 'r', carrying a charge q, into the large one and place it at the centre. The potential due to this new charge has following values.

Potential due to small sphere of radius r carrying charge $q = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Potential at the surface of large shellof radius R $= \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$.

Taking both charges q and Q in to account we have for the total potential V and the potential difference given by,

$$V(R) = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{q}{R}\right)$$

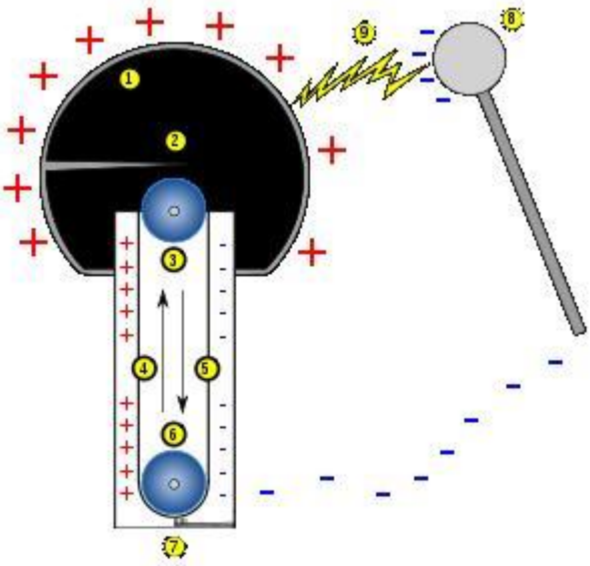
$$V(r) = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{q}{r}\right)$$

$$V(r) - V(R) = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{R}\right)$$

Now assume that *q* is positive. We see that, independent of the amount of charge Q that may have accumulated on the larger sphere, it is always at a higher potential: the difference V(r) - V(R) is positive. The potential due to Q is constant upto radius R and so cancels out in the difference.

This means that if we connect the smaller and larger sphere by a wire, the charge q on the former will immediately flow on to the matter, even though the charge Q may be quite large. The natural tendency is for positive charge to move higher to lower potential. Thus, provided we are somehow able to introduce the small charged sphere into the larger one, we can in this way pile up larger and larger amount of charge on the latter. The potential of the outer sphere would also keep rising, at least until it reaches the breakdown field of air.

Construction:



It consists of a large metal sphere mounted on high insulating supports. An endless belt b, made of insulating material such as rubber, passes over the vertical pulleys P1 and P2. The pulley P2 is at the centre of the metal sphere and the pulley P1 is vertically below P2. The belt is run by an electric motor M. B1and B2 are two metal brushes called collecting combs.
The positive terminal of a high tension source (HT) is connected to the comb B1. Due to the process called action of points, charges are accumulated at the pointed ends of the comb, the field increases and ionizes the air near them. The positive charges in air are repelled and get deposited on the belt due to corona discharge. The charges are carried by the belt upwards as it moves. When the positively charged portion of the belt comes in front of the brush B2, by the same process of action of points and corona discharge occurs and the metal sphere acquires positive charges. The positive charges are uniformly distributed over the surface of the sphere. Due to the action of points by the negative charges carried by the gas in front of the comb B2, the positive charge of the belt is neutralized. The uncharged portion of the belt returns down collects the positive charge from B1 which in turn is collected by B2. The charge transfer process is repeated. As more and more positive charges are imparted to the sphere, its positive potential goes on rising until a surface maximum is reached. If the potential goes beyond this, insulation property

of air breaks down and the sphere gets discharged. The breakdown of air takes place in an enclosed steel chamber filled with nitrogen at high pressure.

Performing the simulation:

Help:

Switch

Turn On/Off: Used to power On/Off the Van De Graaff Generator.
Dissect/Cover: This button used to see the inside of the Van De Graaff Generator.

Slider

Change Length: This is used to change the length of two sphere.

Power On the Van De Graaff Generator by using switch **Turn On**. Change the length and observe the discharging time for a particular distance.

9. Thermo couple Seebeck Effect

Aim:

To verify the relation between thermo emf of a thermocouple and temperature difference between two hot junctions.

Theory:

The conversion of temperature difference to electric current and vice-versa is termed as thermoelectric effect. In 1981, Thomas Johann Seebeck found that a circuit with two dissimilar metals with different temperature junctions would deflect a compass magnet. He realised that there was an induced electric current, which by Ampere's law deflect the magnet. Also electric potential or voltage due to the temperature difference can drive the electric current in the closed circuit.
To measure this voltage, one must use a second conductor material which generates a different voltage under the same temperature gradient. Otherwise, if the same material is used for measurement, the voltage generated by the measuring conductor would simply cancel that of the first conductor. The voltage difference generated by the two materials can then be measured and related to the corresponding temperature gradient. It is thus clear that, based on Seebeck's principle; thermocouples can only measure temperature differences and need a known reference temperature to yield the absolute readings.
The principle behind it states that

$$V = \alpha (T_h - T_c)$$

V- Voltage difference between two dissimilar metals
a- Seebeck coefficient
T_h - T_c - Temperature difference between hot and cold junctions

There are three major effects involved in a thermocouple circuit: the **Seebeck, Peltier**, and **Thomson effects**.
The Seebeck effect describes the voltage or electromotive force (EMF) induced by the temperature difference (gradient) along the wire. The change in material EMF with respect to a change in temperature is called the **Seebeck coefficient** or thermoelectric sensitivity. This coefficient is usually a nonlinear function of temperature.

Peltier effect describes the temperature difference generated by EMF and is the reverse of Seebeck effect. Finally, the **Thomson effect** relates the reversible thermal gradient and EMF in a homogeneous conductor. Thermocouples generate an open-circuit voltage, called the Seebeck voltage that is proportional to the temperature difference between the hot and reference junctions:

$$E = \alpha (T - T_0) + \beta (T - T_0)^2$$

Since thermocouple voltage is a function of the temperature difference between junctions, it is necessary to know both voltage and reference junction temperature in order to determine the temperature at the hot junction. Consequently, a thermocouple measurement system must either measure the reference junction temperature or control it to maintain it at a fixed, known temperature.

Performing the simulation

1. The user has to select the type of thermocouple from the 'Choose ThermoCouple Type' combo box.
2. Adjust the temperature slider to a specific temperature.
3. The emf generated can be viewed through the voltmeter.
4. The temperature versus emf graph can be analyzed.

Variable Region:

1. **Choose ThermoCouple Type:** The user can select different kinds of thermocouple with this combo box.
2. **Hot Temperature Slider:** This slider is used to change the temperature of the hot junction.
3. **Reference Temperature Slider:** This slider is used to change the reference temperature.