VIVA-VOCE

Experiment : 1: SOLAR CELL

1. Define solar cell.
Ans. A solar cell is a device which is basically a P-N junction diode which converts solar energy into electrical energy.

2. Define fill factor.
Ans. It is the ratio of Maximum useful power to the ideal power.

$$\text{Fill Factor (FF)} = \frac{V_m \times I_m}{V_{oc} \times I_{sc}}$$

3. What happened to a photon when it is absorbed by a solar cell?
Ans. If the energy of the photon is greater or equal to the band gap energy than it may generate an electron-hole pair. If the energy is less than the band gap energy, it produces excitation.

4. What is the conversion efficiency range of a silicon cell?
Ans. 10 to 15 %

5. What is the range of fill factor for silicon?
Ans. 0.65 to 0.80

Experiment : 2: P- N JUNCTION DIODE

1. What is semiconductor diode?
Ans. A p-n junction is called semiconductor diode.

2. Define depletion layer?
Ans. The region having uncompensated acceptor and donor ions is called depletion layer.

3. What do you mean by forward bias and reversed bias?
Ans. When p-type semiconductor is connected to the positive terminal and n-type semiconductor connected to negative terminal of voltage source, so that zero resistance is offered to the flow of current, is called forward bias. When p-type semiconductor is connected to the negative terminal and n-type semiconductor connected to positive terminal of the voltage source, so that zero current flows in this condition, is called reverse bias.

4. Define knee voltage?
Ans. The forward voltage at which current through the junction starts increasing rapidly.

5. Define break down voltage?
Ans. The reverse voltage at which p-n junction breaks down which sudden rise in reverse current.

6. What is doping?
Ans. Addition of impurity atoms to a pure semiconductor in controlled manner toincrease the conductivity is called doping.

Experiment : 3 :LASER

1. **What is diffraction?**
   Ans. Diffraction occurs when waves bend around small obstacles, or when waves spread out after they pass through small openings.
2. **What is interference?**
   Ans. Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude.
3. **What is monochromatic light give examples?**
   Ans. Monochromatic light refers to light that is of one color.
   Therefore, monochromatic light would emit just one of these colors.
   Examples of monochromatic lights are. Sodium Vapour Lamp (Commonly Used) Laser beam.

4. **What is mean by diffraction grating?**
   Ans. Diffraction grating: A polished surface, usually glass or metal, having a large number of very fine parallel grooves or slits, and used to produce optical spectra by diffraction of reflected or transmitted light.

5. **What is the diffraction angle?**
   Ans. Diffraction Angle. The angle that lies between the direction of an Incident Light beam and any resulting diffracted beam.

6. **What are 3 types of lasers**?
   Ans. Laser Media: Lasers are commonly designated by the type of lasing material employed. There are four types which are: solid state, gas, dye, and semiconductor.

7. **Why do people use lasers?**
   Ans. Lasers are brighter and more focused than other light sources. One place where lasers are used is in surgery. Lasers are also used in surveying, because they provide straight lines. Lasers are also used in manufacturing for cutting and positioning of equipment.

Experiment : 4 :HALL EFFECT

1. Define Hall Effect?
Ans. When a current carrying specimen is placed in a transverse magnetic field then a voltage is developed which is perpendicular to both, direction of current and magnetic field. This phenomenon is known Hall Effect.

2. What causes Hall Effect?
Ans. Whenever a charge moves in a mutually perpendicular electric and magnetic field it experiences Lorentz force due to which it deflects from its path and Hall voltage is developed.

3. What is Lorentzforce?
Ans. If charge ‘q’ moves in a magnetic and electric field ‘B’ &’E’ respectively with velocity v then force on it is given by
$F= qE+ Bqv.\sin\theta$

4. What is Hall Coefficient?
Ans. It is the electric field developed per unit current density per unit magnetic field

5. What are the uses of Hall Effect?
Ans. To determine the sign of charge carrier and charge carrier concentration

6. Define Charge carrier concentration.
Ans. No. of charge carriers per unit volume.

7.Why Hall voltages differ for different type of charge carrier?
Ans. Because direction of Lorentz force is different for different type of charge carrier.

8.What is unit Hall coefficient?
Ans. Ohm-meter/Tesla.

9. What is the unit of charge carrier concentration?
Ans. per Cubic-centimeter.

10. Which type of magnet is used in the experiment, temporary or permanent?
Ans. Temporary.

11. Which type of charge has greater mobility?
Ans. In semiconductors, electron has greater mobility than holes.

Experiment : 5 : OPTICAL FIBER

1. **What is semiconductor diode laser?**
   Ans. Semiconductor diode laser is a specially fabricated pn junction diode. It emits laser light when it is forward biased**.**

2. **What is LASER?**
   Ans. The term LASER stands for Light Amplification by Stimulated Emission of Radiation. It is a device which produces a powerful, monochromatic collimated beam of light in which the waves are coherent.

3. **What are the characteristics of laser radiation?**
   Ans. Laser radiations have high intensity, high coherence, high monochromaticity and high directionality with less divergence.

4. **Define numerical aperture.**
   Ans. Numerical aperture is defined as the light gathering capability of an optical fiber. It is the sine of the acceptance angle. NA=sinθ_a

5. **What is the principle used in fiber optic communication system?**
   Ans. The principle behind the transmission of light waves in an optical fiber is total internal reflection.

Experiment : 6 : TORSIONAL PENDULUM

1.What is torsional pendulum?
Ans.A body suspended from a rigid support by means of a long and thin elastic wire is called torsional pendulum.

2.What is the type of oscillation?
Ans. This is of simple harmonic oscillation type.

3.On what factors does the time period?
Ans. It depends upon I) moment of inertia of the body II) rigidity of wire i.e., length, radius and material of the wire.

4.How will you determine the rigidity of fluids?
Ans. As fluids do not have a shape of their own, hence they do not possess rigidity. Hence there is no question of determining.

5.What is meant by rigidity modulus?
Ans. It is defined as the ratio of shearing stress to shearing strain

Experiment : 7 : WAVELENGTH OF LASER SOURCE BY DIFFRACTION GRATING

1. **Define diffraction?**
   Ans. Bending of light waves at the orifice of the obstacle is termed as diffraction.

2. **What do you understand by Grating?**
   Ans. A plane glass plate which consist of large number of equidistant opaque rulings by using fine diamond pen.

3. **What is grating element?**
   Ans. It is the distance between two successive ruled lines.

4.What is the abbreviation of LASER?

Ans.L – Light

A - Amplification by
S – Stimulated
E - Emission of
R - Radiation.

5.What is the principle of Laser?

Ans. A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic.

6. What are the advantages of lasers?

Ans. Lasers are used for cutting metal sheets, they are used in electronic communication systems, they are used to cure tumors on eye surface., etc.,

Experiment : 8 : THERMISTOR

1. **What is thermistor?**
   Ans. The component whose resistance is very sensitive to temperature variation is called thermistor.

2. **What is the condition of Wheatstone bridge?**
   Ans. Wheat stone bridge is balanced when galvanometer shows null deflection
   i,e.,$\frac{P}{Q} = \frac{R}{S}$

3. **How thermistors are fabricated?**
   Ans. They are made up of mixtures of oxides of cobalt, magnesium, manganese and nickel or uranium. They come in variety of sizes and shapes like beads, washers, rods etc

4. **What is the difference between galvanometer and Ammeter?**
   Ans. Galvanometer are used in electrical circuit to know the presence of current.Whereas, Ammeter are used to measure small current.

5. **Classify thermistor based upon temperature coefficients?**

1) Positive temperature coefficient (PTC) thermistor: -resistance increase with increase in temperature.
2) Negative temperature coefficient (NTC) thermistor: -resistance decrease with increase in temperature.

6. **What are the applications of thermistor?**
   Ans. They are used in refrigerators, ovens, fire alarms

VIVA-VOICE

Q. 1 What is four probe method?

Ans: In four probes method there is a set of four probes. Outer pair is used for passing current through the semiconductor and the inner pair is used for measuring potential difference by using suitable relationship we can measure the resistivity of given semiconductor.

Q. 2 What is resistivity?

Ans. The resistance offered by a conductor of unit cross-sectional area and of unit length is called resistivity. It is the property of the material of the conductor (unit: ohm-cm).

Q. 3 What are the factor that control the resistivity of a semiconductor?

Ans. Temperature and bandgap.

Q. 4 How does the resistivity of a semiconductor vary with rise in temperature?

Ans. It decreases.

Q. 5 What is the position of the Fermi-level in n-type and p-type semiconductor?

Ans. In an n-type semiconductor, the concentration of electrons is more so the Fermi-level lies nearer to the conduction band.

In a p-type semiconductor, the concentration of holes is more so the Fermi-level lies nearer to the valence band.

Q. 6 How do you differentiate among a conductor, an insulator and a semiconductor based on forbidden energy-gap?

Ans. In conductors, the conduction band and the valence band overlap consequently the energy-gap is zero. In semiconductors, there is a small energy-gap (of the order of leV) between the conduction band and the valence band.

1. DETERMINATION OF WAVELENGTH OF LASER LIGHT USING DIFFRACTION GRATING

Aim:

To determine the wavelength of the laser light using diffraction grating.

Apparatus:

Diffraction grating, He-Ne laser or Semiconductor laser, optical bench and screen or scale arrangement.

Formula:

Wavelength of laser light $\lambda = \dfrac{\sin\theta}{nN}$

where 'θ' is the angle of diffraction

'N' is the number of lines per cm in grating = $\frac{2.54}{2500}$; (One inch =2.54cm)

'n' is the order of the spectrum

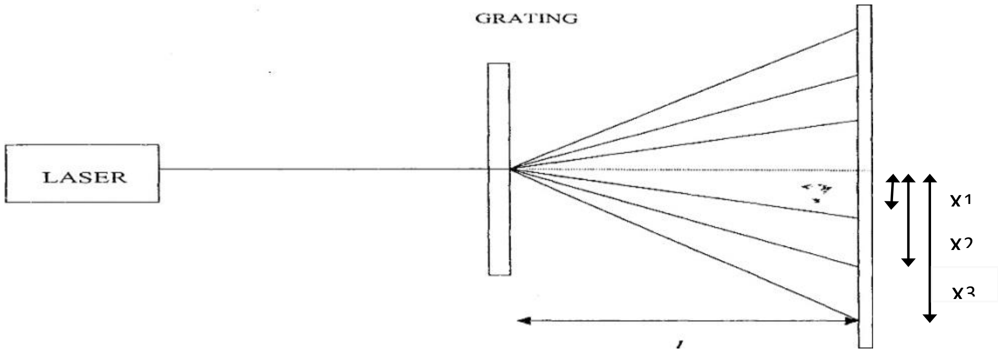


Fig. 1. Experimental Setup

The experiment is repeated for at least three P values (15cm, 20cm &25cm).

Knowing the values of θ, n & N, the wavelength of laser light can be calculated using the formula $\lambda = \sin\theta / nN$

Observation:

S. No.	order	D (cm)				$(\sqrt{x^2 + D^2})$	Sin θ = $(x_n/\sqrt{x^2 + D^2})$	λ = Sinθ /nN
			LHS	RHS	Mean (x_n)			
1	1							
2	2							
3	3							
4	1							
5	2							
6	3							
7	1							
8	2							
9	3							

Precautions:

1) Laser experiment should be performed in the dark room.

2) Do not see the laser light directly.

Result: Wavelength of laser source is …………

2. NUMERICAL APERTURE AND ACCEPTANCE ANGLE OF AN OPTICAL FIBRE

AIM :

To determine the acceptance angle and numerical aperture of the given fibre optic cable.

APPARATUS :

Diode laser source, fibre optic cable and NA

FORMULA:

- Numerical aperture of the given optical fibre NA = Sinθ_{max}
- NA = $\frac{w}{\sqrt{4L^2+w^2}}$

where θ_{max} is the acceptance angle of the fibre

'w' is the diameter of the laser spot noted on the screen

'L' is the distance of the screen from the fibre end

The numerical aperture of the optical fibre system is computed using the formula,

NA = μ0 sinθ_{max} = $\frac{w}{\sqrt{4L^2+w^2}}$

where μ_0 is the refractive index of the medium. For air $\mu_0 = 1$, hence NA $= \sin\theta_{max}$ and θ_{max} is the acceptance (maximum-ray) angle of the fiber.

Acceptance angle of the optical fiber

$\theta_{max} = \sin^{-1}(\text{NA})$

Observation Table:

Sl.No.	Distance of the spot from fibre end (L)	Diameter of spot in	NA = $\frac{w}{\sqrt{4L^2+w^2}}$	$\theta_{max} = \sin^{-1}(\text{NA})$

Precautions:

1)Optical source should be properly aligned with the cable.
2)Distance of the launch point from cable should be properly selected to ensure that maximum amount of optical power is transferred to the cable.

Result:

Numerical aperture of the given fiber optic cable =

Acceptance angle of the fiber =

3. SOLAR CELL

AIM: To draw the V-I characteristics of a solar cell and calculate the fill factor (FF) and series resistance (R_s)

APPARATUS: Solar Cell, , Voltmeter, Micro ammeter, Potentiometer, and connecting wires.

Formulae:

$$\text{Fill Factor} = \frac{I_m V_m}{I_{Sc} V_{OC}}$$

I_m is the maximum currents.

V_m is the maximum voltage.

I_{sc} is the short circuit current.

V_{oc} is the open circuit voltage

Series Resistance = $1/2[\Delta V_1 / \Delta I_1 + \Delta V_2 / \Delta I_2]$

Circuit Diagram:

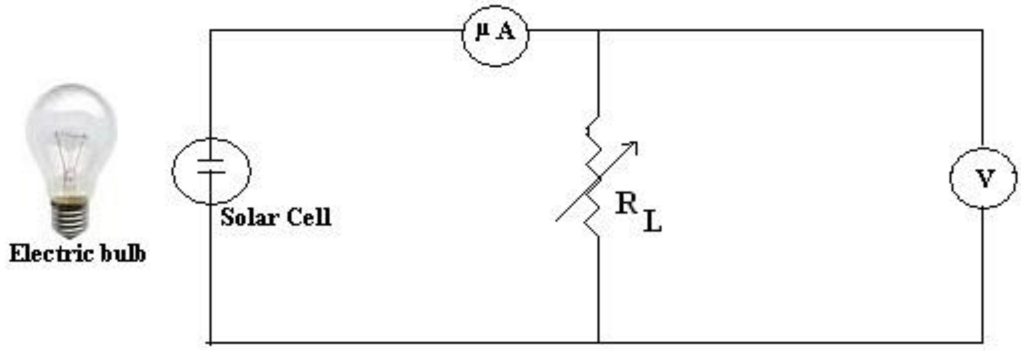
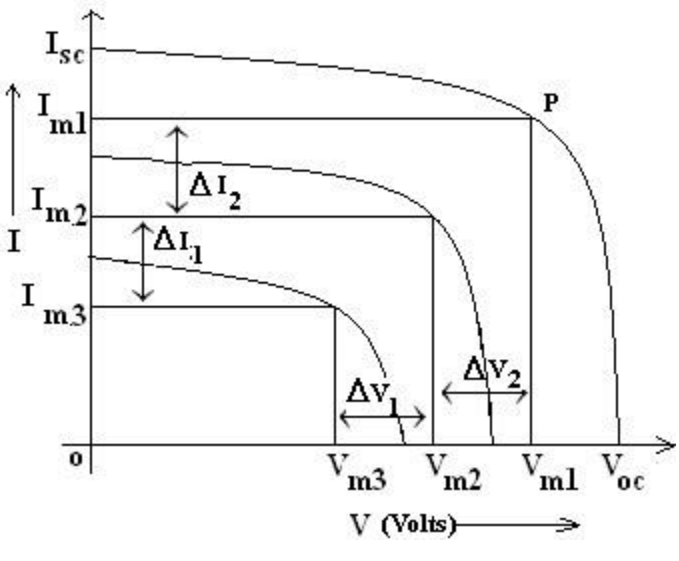


Figure – 1(a): equivalent circuit of a solar cell.

To find out the series resistance, find the difference between two consecutives.

Vm's and Im's (i.e. {ΔV_1, ΔV_2, ΔI_1 & ΔI_2 as shown in figure 2) from the graph.



Observations & Calculations:

V_{oc} =	I_{sc}=		V_{oc} =	I_{sc}=		V_{oc} =	I_{sc}=	
S.No.	**Voltage V**	**Current μA**	**S.No.**	**Voltage V**	**Current μA**	**S.No.**	**Voltage V**	**Current μA**
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

Precautions:

1) Light from the source should fall vertically on the solar cell.

2) Readings should be tabulated carefully without parallax error.

RESULT:

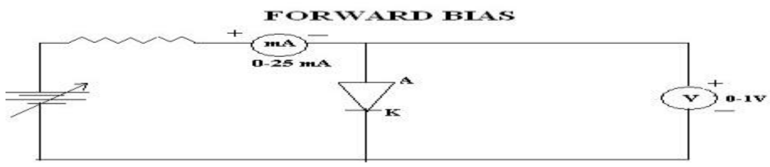
1. Fill factor (F) = ………
2. Series Resistance (Rs) = ……………………

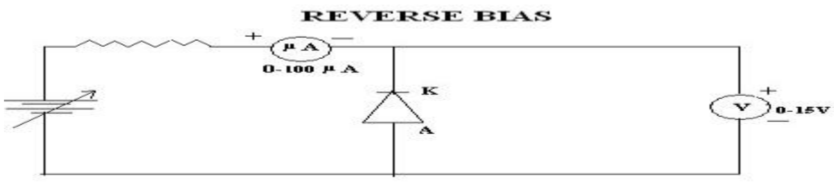
4. P – N JUNCTION DIODE

AIM : To study the V-I characteristics of the given p-n Junction diode and to determine forward bias and reverse bias resistance

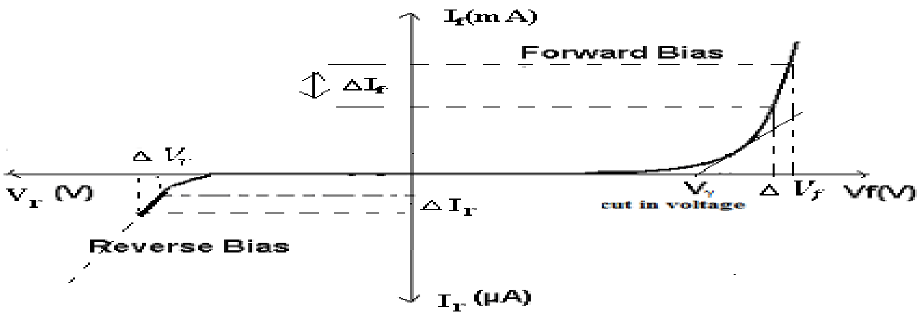
APPARATUS: Junction Diode kit, Connecting Wires.

Circuit Diagrams





V-I Characteristics of the Diode (Graph)



Observations& Calculations:

S.No.	Observations	Forward Bias	S.No	Observations	Reserves Bias
	Voltage (V)	Current (mA)		Voltage (V)	Current (µA)

Precautions:

1) While doing the experiment do not exceed the readings of the diode. This may lead to damaging of the diode.
2) Do not switch on the power supply unless you have checked the circuit connections as per the circuit diagram .

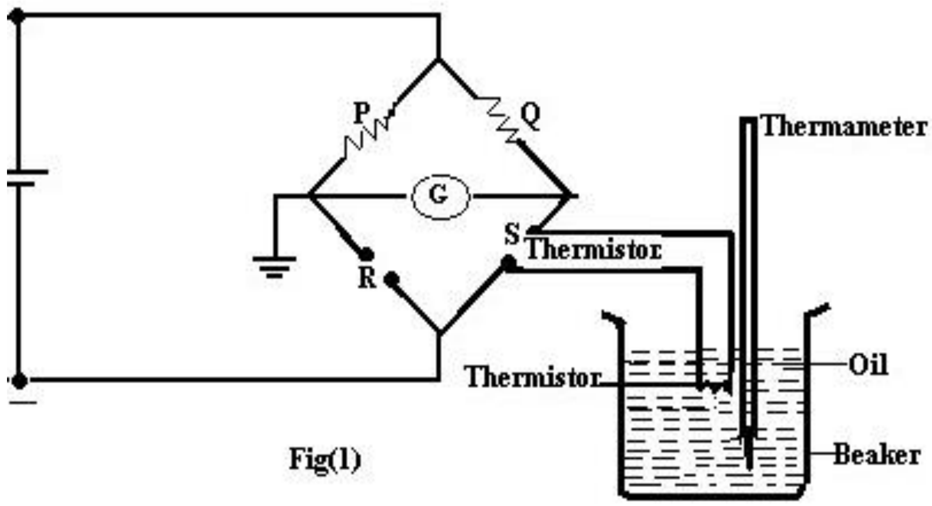
Result: 1. The V-I Characteristics of the given junction diode have been verified.
2. Forward bias resistance is ………. And Reverse bias resistance is ………

5. TEMPERATURE CHARACTERISTICS OF A THERMISTOR

AIM: To draw the temperature - resistance characteristics of thermistor and to evaluate the constants.

Apparatus: Thermistor, Thermistor characteristics Kit, connecting wires, beaker containing oil, thermometer and heater.

Circuit Diagram:



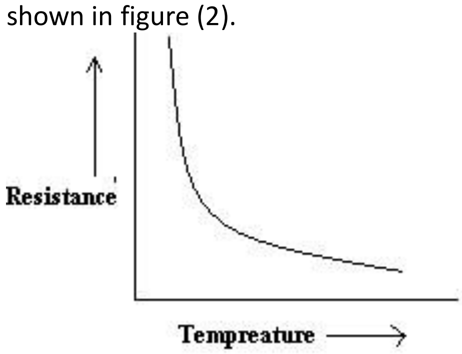
Fig(1)

Procedure: A wheat stone bridge is set up as shown in the figure (1) make connections as shown in figure (1).

The thermistor is connected in the fourth arm of the bridge while P, Q, R form the other three arms. P and Q represent the ratio arms. Take P=Q=470 Ohms and balance the bridge with the thermistor in the beaker containing oil maintained at the room temperature. The value of R which is obtained for balancing the bridge gives the resistance of the thermistor at room temperature. Heat the beaker till the temperature of oil reaches 80^0C and now again determine the value of R that balance the bridge.

Similarly determine the resistance (R) of the thermistor at regular intervals of 5^0C each, while cooling. Tabulate the results in the tabular form.

Draw a graph between resistance and absolute temperature. It should be as shown in figure (2).



Fig(2)
Tempreature Char of Termistor

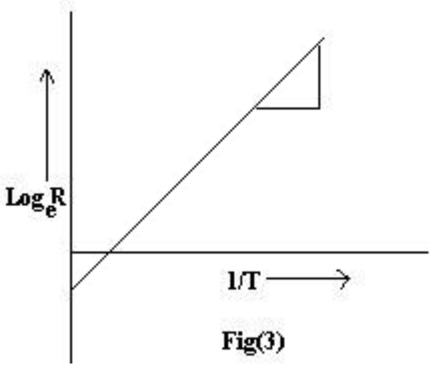
It is noted that R decreases exponentially with increase in temperature.

EVALUATION OF CONSTANTS 'A' AND 'B'

The resistance of the thermistor is given by $R = Ae^{B/T}$ __________ (1)

Taking logarithms on both sides we get $\log_e R = \log_e A + \frac{B}{T}$ __________ (2)

Now draw a graph with $\log_e R$ on the y-axis and I/T on the x-axis. A straight-line graph is obtained with negative intercept on the y-axis (as shown in fig. 3)



Fig(3)

The slope of the line gives B.

To calculate the constant A take the logarithm to the base 10 of the formula (1). then

Log_{10} R = Log_{10} A + B Log_{10} eT

Log_{10} A = Log_{10} R $\underline{B}$ (0.4343)

Hence take the value of R corresponding to some temperature T K and substitute in

eq. (3) along with the value of B already evaluated.

OBSERVATIONS:

S.No	Temperature of Thermistor		1/T	Resistance of the thermistor (R)	Log_{10} R
	T^0C	T K			

Precautions:

1) The heating arrangement must be kept at a suitable distance away from the rest of the circuit.

2) Readings should be carefully tabulated while the temperature slows down.

RESULTS:

The Temperature characteristics of the given thermistor is drawn and

1. The value of Constant A =------------ Ω

2. The value of Constant B=------------- K

6.ENERGY GAP OF A SEMICONDUCTOR

AIM: To determine the Electrical conductivity and Energy Band Gap of a semiconductor using Four Probe method.

APPARATUS:

A four-point probe arrangement, a semiconductor sample, a constant current power supply with built in digital milliammeter and digital millivoltmeter, digital temperature indicator with sensor and built in heater.

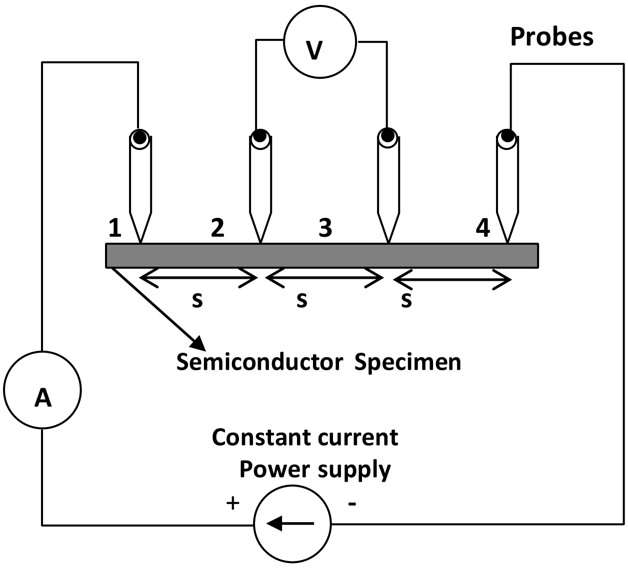
FORMULA:

The energy band gap of the semiconductor Eg is given by

2.3026X2XK X $\log_{10} \rho$

Eg = ______________________ **(in eV)**
1/T (in Kelvin)

Where Eg – Band gap of the material
T – Temperature in kelvin
K – Boltzmann constant, K – **8.6×10^{-5}eV/K**. Resistivity of the Semiconductor



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

OBSERVATIONS:

I. N O	TEMPERATURE IN ^{O}C	TEMPERATURE IN KELVIN	1/TX 10^{-3}	Voltage (mv)	ρ (Ω, cm)	$\log_{10} \rho$

Precautions:

1) The Germanium or Silicon crystal is very brittle as such only minimum pressure was applied on it for proper electrical contact.

2) The experiment can be repeated only after two hours of gap.

Result: The energy band gap of the semiconductor is …………. eV.
Electrical conductivity at room temperature is………..(ohm-cm)$^{-1}$

7. HALL EFFECT

AIM: To determine Hall Coefficient, Nature of charge carriers, Carrier Density & Carrier Mobility (Lorentz Force) of a semiconductor crystal.

APPARATUS: I.C regulated power supply, Electromagnets, Constant current power supply, Hall Sensor & Semiconductor Crystal.

Formulae:

Crystal type = Germanium p-type
Size = 5mm x 5mm
Thickness of the crystal (Z) = 0.7mm

Sample calculation for Hall Coefficient, Carrier Density & Carrier Mobility

Thickness of the Crystal (Z) = 0.7mm= 0.07cm

Resistivity (□) = 2.3578625 ohm m

Conductivity (□) = 0.4241129 col $volt^{-1}$ $sec^{-1}m^{-1}$

Calculation of Hall Coefficient (RH)

Hall Coefficient (R_H) = $\frac{V_H \times Z}{I \times B}$

Where V_H/I = Slope of 2KG graph Z = Thickness of the crystal

B = Magnetic Field (2KG in this case)

Substituting the values in the equation :

Hall Coefficient (R_H) = $\frac{20.478 \times 7 \times 10^{-2}}{2 \times 10^3}$

$= 71.673 \times 10^3$ cm^3 col^{-1}

As per the calculation since the sign of Hall coefficient is positive, the semiconductor is P-type.

Calculation of Carrier Density :

Carrier Density (n) = 1/ (R_H x q)

R_H= Hall Coefficient

q= Charge of an electron = 1.6 X 10^{-19} Coulombs

$= \frac{1}{71.673 \times 10^3 \times 1.6 \times 10^{-19}}$

$= 8.7201 \times 10^{13}$ cm^3

Calculation of Carrier Mobility:

Carrier Mobility (μ) = R_H x

R_H= Hall Coefficient

=Conductivity

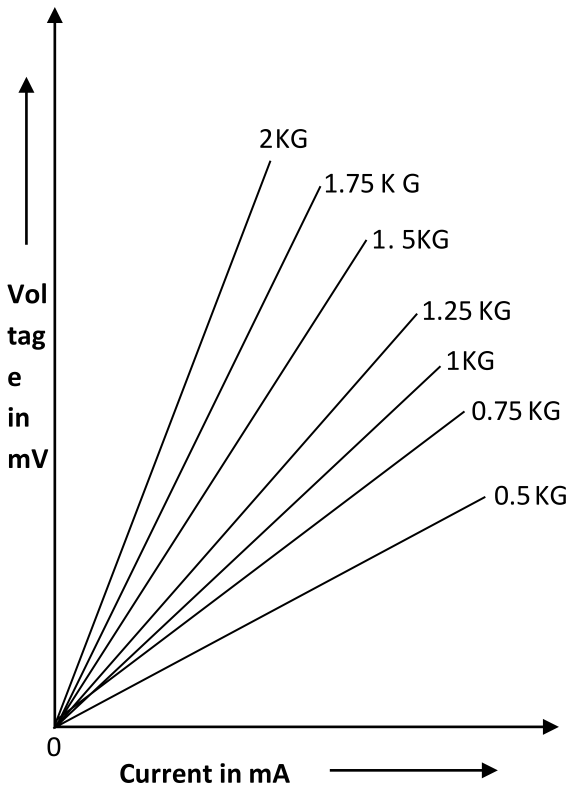
$= 71.673 \times 10^{3} \times .4477163$

$= 32089.185 \times 10^{-2}$ cm volt^{-1} sec^{-1}

Observations:

TABULAR COLUMN: **IDEAL GRAPH:**

SI NO	HALL CURRENT I,mA	HALL VOLTAGE V,mV
1	0.1	
2	0.2	
3	0.3	
4	0.4	
5	0.5	
6	0.6	
7	0.7	
8	0.8	
9	0.9	
10	1	
11	1.1	
12	1.2	
13	1.3	
14	1.4	
15	1.5	
16	1.6	
17	1.7	
18	1.8	
19	1.9	
20	2	
21	2.1	
22	2.2	
23	2.3	
24	2.4	
25	2.5	



Precautions:

1. The crystal contacts in Hall probe should neither the loose nor to be tight. The crystal is thin and very brittle.
2. The current through the crystal should not be large enough to cause heating. It should not be exceeding 10mA.

8.Torsional pendulum

Aim:

To determine the rigidity modulus of the suspension wire of given material using torsional pendulum.

Apparatus:

The given torsion pendulum, a circular brass disc provided with check nut at its center, stopwatch, meter scale, screw gauge and Vernier calipers.

Formulae:

$$n = \frac{8\pi I l}{r^4 T^2} \quad \ldots\ldots\ldots\ldots (A)$$

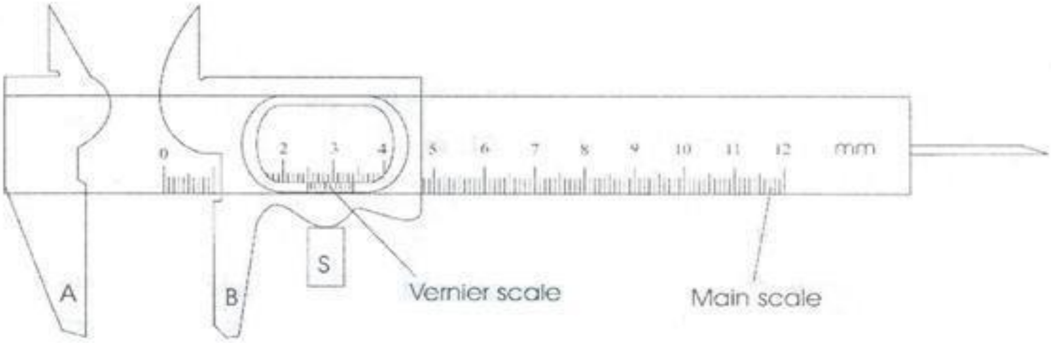
Where l =length of the suspension wire; r=radius of the wire; n=rigidity modulus of the suspension wire; T = time period of torsion pendulum; I = moment of inertia of the disc.

We can use the above formula directly if we calculate the moment of inertia of the disc, I as

$$I = \frac{MR^2}{2}$$

Where M is the mass of the disc and R is the radius of the disc.

Vernier Calipers:



To find the Least Count (LC) of the Vernier calipers:

It is the smallest length that can be measured accurately by the Vernier calipers and is measured as the difference between one main scale division and one Vernier scale division.

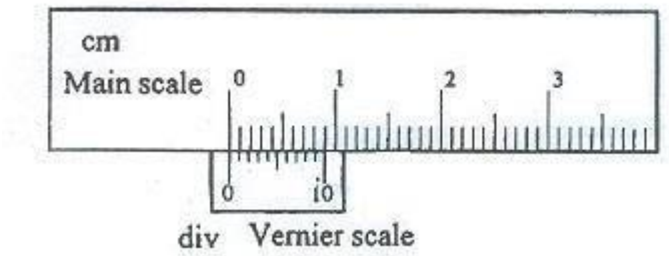


Fig. 1 Vernier scale and main scale

Least Count (LC) **=** 1 M.S.D — 1 V.S.D

Value of 1 M.S.D = 1 mm

No of divisions on the vernier scale = 10 divisions.

10 V.S.D =9 M.S.D

1 V.S.D =9/10 M.S.D = 9/10 x 1 mm = 9/10 mm L.C.=1 M.S.D —1 V.S.D

= 1 mm - 9/10 mm

= 0.1 mm = 0.01 cm

L.C. = 0.01 cm

To find the least count (LC) of the screw gauge

Least count of a screw gauge is the distance through which the screw tip moves when the screw is rotated through one division on the head scale.

$$Pitch = \frac{Distance\ moved\ by\ the\ head\ scale\ on\ the\ pitch\ scale}{Number\ of\ rotations\ given\ to\ the\ head\ scale}$$

$$Least\ count\ (LC) = \frac{Pitch}{Total\ number\ of\ divisions\ on\ head\ scale}$$

To find the pitch, the head or the screw is given say 5 rotations and the distance moved by the head scale on the pitch scale is noted. Then by using the above formula, the least count of the screw gauge is calculated.

Pitch = 5 mm / 5 = 1 mm

Least Count = 1 mm / 100 = 0.01 mm

The screw head is rotated until the two plane faces A and B are just in contact.

2. To find the zero correction (ZC) **i)** Nil error

If the zero of the head scales coincides with the zero of the pitch scale and also lies on the base line (B.L), the instrument has no zero error and hence there is no zero correction (See Fig.

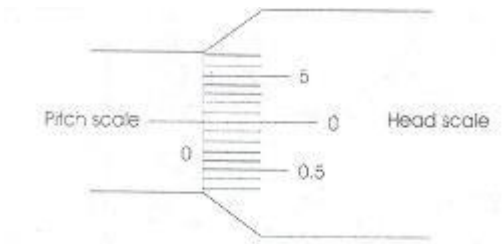


Fig. 2 Nil Error

ii) Positive zero error

If the zero of the head scales lies below the base line (B.L) of the pitch scale then the zero error is positive and zero correction is negative. The division on the head scale, which coincides with the base line of pitch scale, is noted. The division multiplied by the least count gives the value of the positive zero error. This error is to be subtracted from the observed reading i.e. the zero correction is negative (See Fig.3).

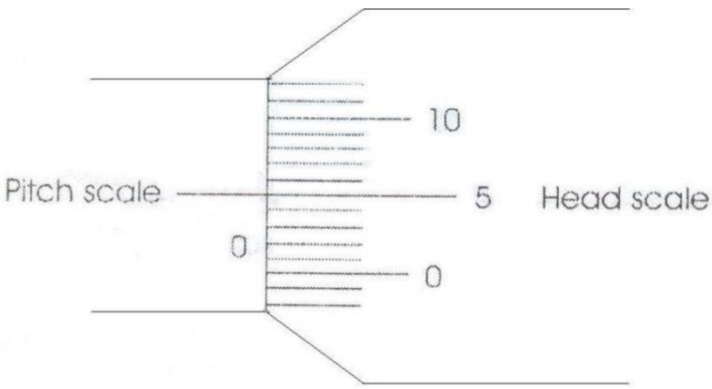


Fig. 3. Positive Zero Error

Example

If 5th division of the head scale coincides with the base line of the pitch scale then

Zero error = +5 divisions

Zero correction = (Z.E x LC) = -(5 x 0.01) = - 0.05 mm.

iii) Negative zero error

If the zero of head scale lies above the base line (B.L) of the pitch scale, then the zero error is negative, and zero correction is positive. The division on the head scale which coincides on the base line of pitch scale is noted. This value is subtracted from the total head scale divisions. This division multiplied by the least count gives the value of the negative error. This error is to be added to the observed reading i.e. zero correction is positive (See Fig. 4).

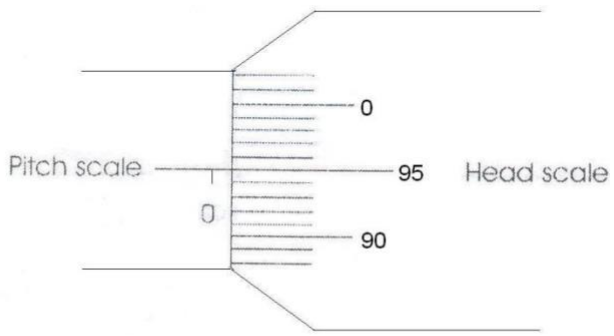


Fig. 4 Negative Zero Error Example

If the 95th division of the head scale coincides with the base line of the pitch scale then, Zero error = -5 divisions

Zero correction = + 0.05 mm

Table1: Radius of the disc (R) in cm (Vernier Calipers)

Sno	MSR (a) in	V.C	V.C×L.C (b)	T=a+b
1.				
2.				
3.				

Radius of the disc is --------------- c.m

Table2: Radius of the wire (r) in cm (Screw Gauge)

Sno	PSR (a)	HSR	HSR×L.C (b)	T=a+b
1.				
2.				
3.				

Radius of the Wire is --------------- c.m

Observations:

Table3: Mean value of $\frac{I}{T^2}$

S.NO	Length of the wire(cm)	Time taken for 20 oscillations in Sec			Time period (T) sec	T^2	$\frac{I}{T^2}$
		Trial1	Trial2	Average			
1	90						
2	80						
3	70						
4	60						
5	50						
6	40.						

1. **Mass of the disc = M= -------------gm.**

2. **Radius of the disc = R=---------cm.**

3. **Radius of the Wire = r =---------cm**

4. **Average value of** $\frac{I}{T^2}$ = ------------cm **Calculations:**

$$\eta = \frac{4\pi M R^2}{r}\left(\frac{I}{T^2}\right).$$

Precautions:

1) It should be oscillated in a vertical plane.

2) The amplitude of the oscillation of a torsional pendulum should be small.

Result: The rigidity modulus of the material of the wire is -----------