RAJIV GANDHI UNIVERSITY OF KNOWLEDGE TECHNOLOGIES
ANDHRA PRADESH
(RGUKT-AP)

Catering to the Educational Needs of Gifted Rural Youth of Andhra Pradesh
(Established by the Govt. of Andhra Pradesh and recognized as per Section 2(f) of UGC Act, 1956)

ONGOLE CAMPUS

ENGINEERING PHYSICS LAB

EXPERIMENTAL LAB MANUAL

FOR

1st YEAR B.Tech. STUDENTS

ACADEMIC YEAR
2022-23

LIST OFEXPERIMENTS

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Experiment No. 1 **Dt.: ..../...../.......**

Wavelength of laser light - Diffraction grating

Aim: To determine the wavelength of laser beam using diffraction grating.

Apparatus: Laser source (Diode laser), Diffraction grating, Optical bench, Screen, Meter scale.

Formula:

Wavelength of the laser,

$$\boldsymbol{\lambda} = \frac{\sin\theta}{nN},$$

where θ is the angle of diffraction, n is the order of diffraction pattern and N is the number of lines per cm on grating.

Procedure:

Arrange laser source, diffraction grating and screen rectilinearly at the same height on the optical bench. Keep the distance (D) between the grating and the screen at a typical value (say 10 cm). Switch on the laser source so that the laser beam incident normally on the surface of grating. Then laser beam gets diffracted from the ruled surface of grating and form a diffraction pattern on the screen. We can observe different diffraction orders of bright spots on the screen on either sides of the central maximum. Now measure the distance between the spots of the same order from the central maximum. Let the distance from the central maximum to diffracted spot on left side is d_1 and that on the right side is d_2. Obtain the diffraction angle θ and N values. The wavelength of the given laser beam can be determined using the formula, $\boldsymbol{\lambda} = \frac{\sin\theta}{nN}$. Repeat the experiment for different values of D (D = 10, 15, 20 cm) and note the corresponding 'd' values for different diffraction orders and tabulate the readings. Calculate the average value of wavelength.

Precautions:

1. Laser source, diffraction grating and screen should be rectilinear at the same height.
2. Laser light should not be seen directly.
3. Laser light should incident normally on the surface of the grating.

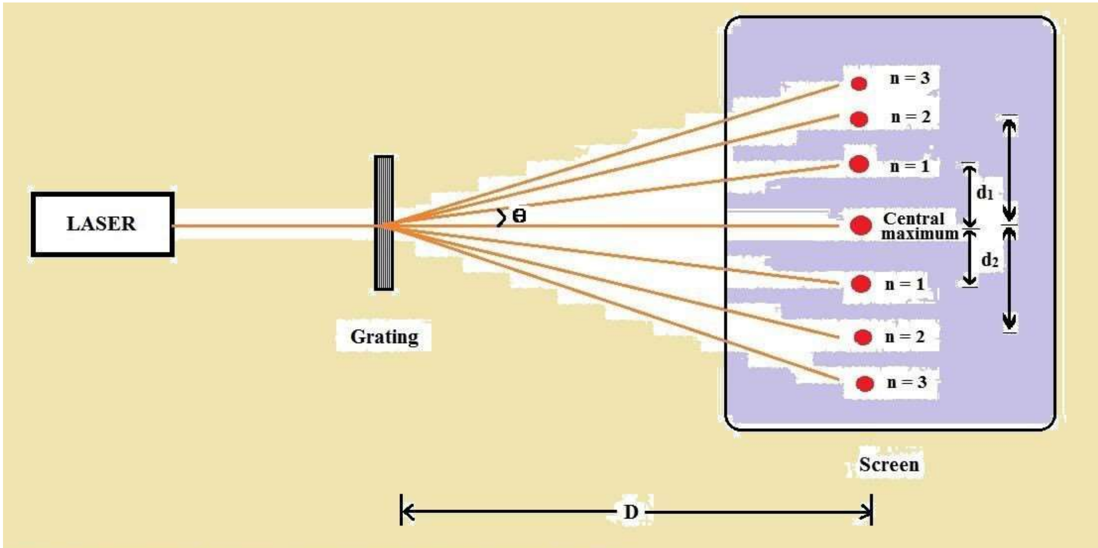

Fig. Experimental setup for determination of wavelength of laser light.

Observations: Number of lines per cm on grating, N = ...

Table: Determination of wavelength of laser light.

S. No.	Distance between grating and screen D (cm)	Diffraction order n	Distance of the diffracted spot from central maximum d (cm): Left side d_1	Right side d_2	Average $d = \frac{d_1 + d_2}{2}$	$\sin\theta = \frac{d}{\sqrt{(D^2 + d^2)}}$	$\lambda = \frac{\sin\theta}{n\,N}$ (cm)
1	10	1					
		2					
2	15	1					
		2					
3	20	1					
		2					

………………

………………

Average λ = ------------------ cm

= ------------------ Å

Calculations:

Result: The wavelength of given laser is determined as **λ** = …………… Å.

Experiment No. 2 **Dt.: …./…../…….**

Optical Fiber -Numerical Aperture

Aim: To determine the numerical aperture and maximum acceptance angle of an optical fiber.

Apparatus: PMMA fiber cable, Fiber optic LED, NA jig.

Formula:

1. Numerical Aperture, $\boldsymbol{NA = \frac{W}{\sqrt{W^2+4L^2}}}$, where W is the diameter of the spot and L is the distance between the fiber end and screen.

2. Maximum acceptance angle, $\boldsymbol{\theta_m = \sin^{-1} NA}$

Procedure:

Connect one end of the fiber optic cable to fiber optic LED and the other end to the NA jig as shown in figure. When A.C. main is switched on, light should appear at the other end of the fiber on the NA jig. Hold the concentric circular scaled white screen vertically at a suitable distance to see that the circumference of any one of the nine concentric circles having diameters 5, 10, 15, 20, 25, 30, 35, 40 and 45 mm exactly coincides with the circumference of the red spot of LED light coming from the fiber end. Note the distance (L) between the screen and the fiber end and diameter (W) of the spot on the screen. Calculate the NA using the formula, $NA = \frac{W}{\sqrt{W^2+4L^2}}$ and maximum acceptance angle using the formula $\theta_m = \sin^{-1} NA$. Repeat the experiment for different distances (L) to their corresponding spot diameters (W) and tabulate the readings. Calculate the average NA and average θ_m.

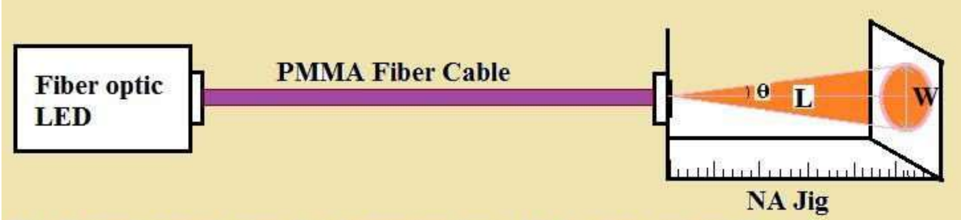

Fig. Experimental setup for determination of NA of an optical fiber.

Precautions:

1. The intensity of light at the output of the fiber optic cable should be maximum at all the times.
2. The fiber optic cable is made free from twists and strains.
3. The circumference of the spot must coincide with the circle.

Table: Determination of NA and Acceptance angle.

S. No.	Diameter of the spot **W (mm)**	Distance of the screen from the fiber end **L (mm)**	$NA = \frac{W}{\sqrt{W^2 + 4L^2}}$	Max. acceptance angle $\theta_m = \sin^{-1} NA$ **(degrees)**
1.	5			
2.	10			
3.	15			
4.	20			
5.	25			
6.	30			

……………… ……………...

……………… ……………...

Average NA = --------------------

Average θ_m = -------------- degrees.

Calculations:

Result:

The Numerical Aperture of the given fiber cable, NA = ---------------- and
The maximum acceptance angle of the optical fiber, θ_m = -------------- degrees.

Experiment No. 3 **Dt.: ..../...../.......**

Hall Effect

Aim:

To study the Hall Voltage developed across the sample of a semiconductor material and to calculate the Hall coefficient and the carrier concentration of the sample material.

Apparatus:

Electromagnet of two solenoids, Constant current supply, Digital Gauss meter with Gauss probe, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli ammeter, digital milli voltmeter and Hall probe), connecting wires, semiconductor specimen.

Theory:

If a current carrying conductor/semiconductor specimen is placed in a perpendicular magnetic field, a potential difference will be generated in the specimen 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 metal or n-type semiconductor kept in XY plane having thickness **t** along Z-axis direction. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current **I** flow through the sample along X-direction. If **w** is the width of the sample kept along Y-axis and **t** is it's thickness kept along Z-axis. Therefore, the current density is given by

$$\mathbf{J_x} = \frac{\mathbf{I}}{\mathbf{wt}} \qquad (1)$$

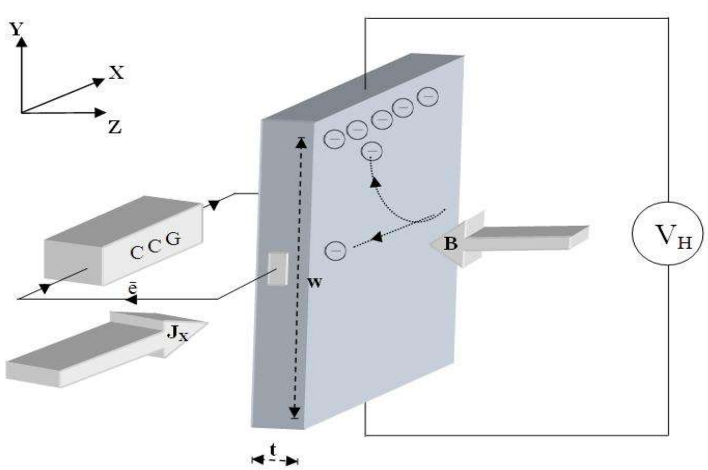

Fig. Schematic representation of Hall Effect in a conductor /n-type semiconductor.
CCG – Constant Current Generator, $\mathbf{J_X}$ – current density, **ē** – electron, **B** – applied magnetic field, **t** – thickness, **w** – width, $\mathbf{V_H}$ – Hall voltage

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 develops a potential difference along Y-axis in between top and bottom surfaces of the specimen known as Hall Voltage $\mathbf{V_H}$ and this phenomenon 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 **B**, the magnetic Lorentz force, $\boldsymbol{F_m} = \boldsymbol{q}(\vec{\boldsymbol{v}} \times \vec{\boldsymbol{B}})$ causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance **qE** 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

$$\mathbf{qE = qvB} \tag{2}$$

Where **q = e** is the electric charge, **E** is the hall electric field developed, **B** is the applied magnetic field and **v** is the drift velocity of charge carriers.

And the current density **J** can be expressed as,

$$\mathbf{J} = \frac{I}{A} = \frac{I}{wt} = \mathbf{nev} \tag{3}$$

Where **n** is the number density of charge carriers in the specimen of length **l**, breadth **w** and thickness **t**. Using (2) and (3) the Hall voltage V_H can be written as,

$$\mathbf{V_H = Ew = wvB = \frac{IB}{net}}, \text{ or}$$

$$\mathbf{V_H = R_H \frac{IB}{t}}, \tag{4}$$

by rearranging eq. (4), we get

$$\mathbf{R_H = \frac{V_H\, t}{I\, B}} \tag{5}$$

Where $\mathbf{R_H}$ is called the Hall coefficient, given by

$$\boldsymbol{R_H = \frac{1}{n\,e}} \tag{6}$$

Formula:

1) Hall coefficient, $\mathbf{R_H} = \frac{\mathbf{V_H}}{I_x} \times \frac{\mathbf{t}}{B_z}$, where

$\mathbf{V_H}$ is the Hall Voltage, $\mathbf{I_x}$ is the Probe current, **t** is the thickness of the semiconductor and $\mathbf{B_z}$ is the applied magnetic field.

2) Carrier concentration (number of charge carriers per unit volume), $\boldsymbol{n} = \frac{\mathbf{1}}{\mathbf{R_H\ e}}$, where **e** is the charge of electron and **R_H** is the Hall Coefficient or Hall constant.

Procedure:

As explained in the theory part (Fig.), the Hall Effect apparatus consists of an in-built constant current generator for supplying current to the specimen along with a digital milliammeter to measure the probe current and a digital millivoltmeter to measure the Hall voltage. The magnetic field generated by the electromagnet can be measured by using a digital gauss meter and gauss probe and the Hall voltage V_H can be measured by using the Hall probe. The detailed experimental procedure can be explained as follows.

1. Connect the electrodes of the electromagnet to the constant power supply unit and confirm the current adjustment knob is extremely anticlockwise.
2. Connect the Gauss probe to the digital gauss meter.
3. Switch on the power supplies for the electromagnet as well as for the digital gaussmeter and calibrate the gaussmeter using zero adjustment knob when no current is passing through the electromagnet (zero magnetic field).
4. By placing the Gauss probe vertically in between the two poles of the electromagnet, slowly increase the current passing through the electromagnet using the current adjustment knob carefully to set a stable magnetic field B_Z, say 0.5 kilo Gauss. Take the Gauss probe out of the electromagnet and keep it aside.
5. Connect the semiconductor specimen to the Hall Effect apparatus (green wires to the ammeter and red wires to the volt meter). Switch on the Hall Effect apparatus.
6. Arrange the Hall probe with the semiconductor specimen vertically in between the N and S poles of the electromagnet oriented along Z-axis as shown in Figure.
7. Slowly set the current passing through the semiconductor specimen to a particular value, say 5 mA using the current adjustment knob in the Hall Effect apparatus.
8. Measure the Hall voltage **V_H** from the milli voltmeter in the Hall Effect apparatus.
9. Repeat steps 4, 6 and 8 to measure the Hall Voltage **V_H** values for different values of applied magnetic fields **B_z** in the range of 0.5 kG to 2 kG at constant probe current (say, **I_x** = 5 mA) and tabulate the observed readings.
10. Calculate the Hall coefficient **R_H** using the formula $\mathbf{R_H} = \frac{\mathbf{V_H}}{\boldsymbol{I_x}} \times \frac{\mathbf{t}}{\boldsymbol{B_z}}$ and average value of **R_H**. Calculate the carrier concentration **n** using the formula $\boldsymbol{n} = \frac{\mathbf{1}}{\mathbf{R_H\ e}}$.

Precautions:

1) Confirm the current adjustment knob is at extremely anticlockwise position before turning on the power supply for the electromagnet.
2) The current through the electromagnet and semiconductor specimen should not exceed their safety limits.
3) While measuring Hall Voltages every time, always keep Hall Probe in the same orientation in between the magnetic poles without contact between the poles and the probe.
4) All the instruments should be carefully handled to avoid any possible damages.

Note: The experiment can also be repeated for different Probe currents at constant magnetic field.

Observations:

1) Thickness of the specimen along magnetic field direction, **t** = ... mm = ... x 10^{-3} m
2) Probe Current $\mathbf{I_x}$ = ... mA.
3) Electron charge, **e** = 1.6 x 10^{-19} Coulomb
4) 1 T = 1 Wb/m^2 = 10^4 G

Table: Experimental readings for determination of the Hall constant.

S. No.	Magnetic Field $\mathbf{B_z}$ (G)	(T or Wb/m^2)	Hall voltage V_H (mV)	Hall Constant $\mathbf{R_H} = \frac{V_H}{I_x} \times \frac{t}{B_z}$ (m^3/C)
1.				
2.				
3.				
4.				
5.				
6.				
7.				

………………

………………

Average value of R_H = ... m^3/C.

Calculations:

Carrier concentration (number of charge carriers per unit volume), $\boldsymbol{n} = \frac{1}{R_H\, e} = \frac{1}{......x.....}$

= .... /m^3.

Result: The Hall Voltages have been studied as a function of applied magnetic field in the given semiconductor specimen and the Hall coefficient and the carrier concentration in the given semiconductor specimen are determined.

1) Hall constant, $\mathbf{R_H}$ =----------------------- m^3/C
2) Number of charge carriers per unit volume, **n** = ----------------- $/m^3$.

Experiment No. 4 **Dt.: ..../...../.......**

Characteristics of p-n junction diode

Aim:

To study the I-V characteristics of a p-n junction diode in forward and reverse biases and to determine its forward resistance and reverse resistance.

Apparatus: Circuit module, DC Regulated power supply (RPS), ammeters (0-50) mA - 1 No., (0-50) µA - 1 No., Voltmeter or Digital Multimeter (DMM), patch Cords.

Circuit diagrams:

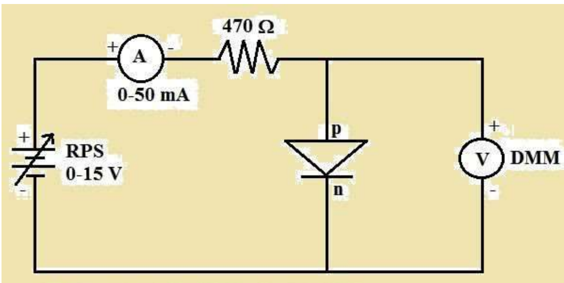

Fig. 1. p-n Junction Diode - Forward Bias.

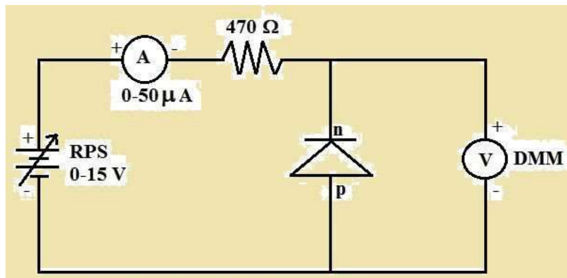

Fig. 2. p-n Junction Diode - Reverse Bias.

Formulae:

If **V**, **I** and **R** represent voltage, current passing and resistance offered by the p-n junction diode, respectively, then the resistances of the diode in forward (F) and reverse (R) biases are given by $\boldsymbol{R_F} = \frac{\Delta V_F}{\Delta I_F}$, and $\boldsymbol{R_R} = \frac{\Delta V_R}{\Delta I_R}$, respectively.

Procedure:

1. Connect the p-n junction diode in forward bias as shown in Fig. 1.
2. Vary the supply voltage in small steps and note down the voltage drop across the diode (represented as forward voltage (V_F)) and current through the circuit (represented as forward current (I_F)). Take more readings at the knee point of characteristics. All the readings are recorded in Table 1.
3. Draw the V-I characteristics (see Fig. 3).
4. Find the forward resistance, $R_F = \frac{\Delta V_F}{\Delta I_F}$ from forward bias characteristics.
5. Connect the circuit for reverse bias as shown in Fig. 2.
6. Vary the supply voltage in steps and study the reverse current (I_R) as a function of reverse voltage (V_R). The readings are recorded in Table 2.
7. Find the reverse resistance, $R_R = \frac{\Delta V_R}{\Delta I_R}$ from reverse bias characteristics (see Fig. 4).

Tabular columns:

Table 1. Forward bias characteristics.

S. No.	V_F (V)	I_F (mA)

Table 2. Reverse bias characteristics.

S. No.	V_R (V)	I_R (μA)

Graphs:

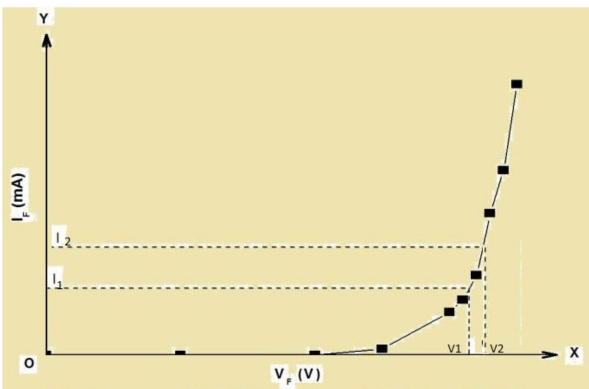

Fig. 3. p-n Junction Diode - Forward Bias Characteristics.

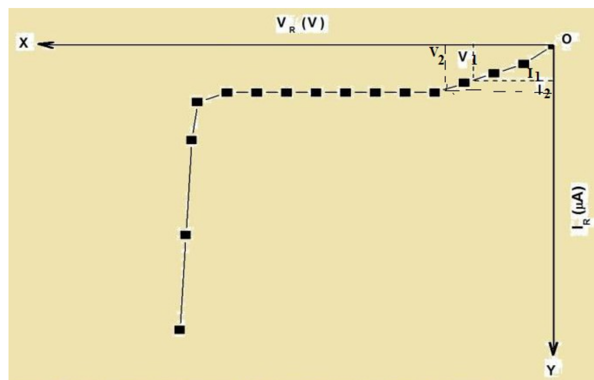

Fig. 4. p-n Junction Diode - Reverse Bias Characteristics.

Calculations:

RESULT:

The I – V characteristics of the p-n junction diode have been studied in forward and reverse biases.

1. The forward resistance of the given diode is found to be R_F = ------------------- Ω and
2. The reverse resistance of the given diode is found to be R_R = ------------------- Ω.

Experiment No. 5 **Dt.: ..../...../.......**

Solar Cell Characteristics

Aim:

To study the I-V characteristics of a Solar Cell and to determine its fill factor.

Apparatus:

Solar cell mounted and fixed on the metal box, Lamp house, Electronics trainer kit consisting of digital voltmeter (0-5 V), digital ammeter (0-250 mA), different types of load resistances selectable using the band switch, patch cards.

Working Principle:

Solar cell is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect, hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor p-n junction diode. device. It is formed by joining p-type (high concentration of hole or deficiency of electron) and n-type (high concentration of electron) semiconductor material. at the junction excess electrons from n-type try to diffuse to p-side and vice-versa. Movement of electrons to the p-side exposes positive ion cores in n side, while movement of holes to the n-side exposes negative ion cores in the p-side. This results in an electric field at the junction and forming the depletion region. When sunlight falls on the solar cell, photons with energy greater than band gap of the semiconductor are absorbed by the cell and generate electron-hole (e-h) pair. These e-h pairs migrate respectively to n- and p- side of the p-n junction due to electrostatic force of the field across the junction. In this way a potential difference is established between two sides of the cell. Typically, a solar or photovoltaic cell has negative front contact and positive back contact. A semiconductor p-n junction is in the middle of these two contacts like a battery. If these two sides are connected by an external circuit, current will start flowing from positive to negative terminal of the solar cell. This is basic working principle of a solar cell. For silicon, the band gap at room temperature is $E_g = 1.1$ eV and the diffusion potential is $U_D = 0.5$ to 0.7 V. Studying the I-V characteristics of a solar cell helps us to evaluate the fill factor and efficiency of the solar cell. A solar panel consists of number of solar cells connected in series and parallel.

The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell defined as the ratio of the maximum power from the solar cell to it's ideal power, the product of V_{oc} and I_{sc}. Graphically, the FF is a measure of the "squareness" of the solar cell and is also the area of the largest rectangle which will fit in the I-V curve.

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. In addition to reflecting the performance of the solar cell itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell.

Formula:

The Fill Factor of the Solar Cell is given by $\boldsymbol{FF} = \frac{\boldsymbol{V_{mp}} \times \boldsymbol{I_{mp}}}{\boldsymbol{V_{oc}} \times \boldsymbol{I_{sc}}}$, where

$\mathbf{V_{mp}}$ is the voltage corresponding to the maximum power, $\mathbf{I_{mp}}$ is the current corresponding to the maximum power, $\mathbf{V_{oc}}$ and $\mathbf{I_{sc}}$ corresponds to the open circuit voltage and short circuit current, respectively. The rating of a solar panel depends on these four parameters.

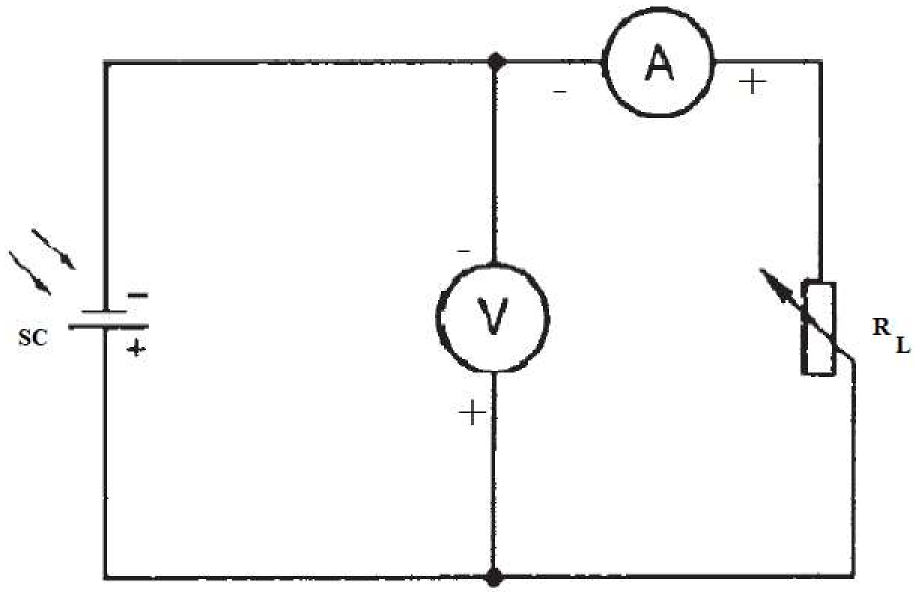

Fig. 1. Circuit for I-V Characteristics of solar cell.

Procedure:

1. Connect the solar cell (SC) to the volt meter (V), ammeter (A), and potentiometer (Load Resistance R_L), as shown in Fig. 1 and set the potentiometer at the minimum.
2. Connect the incandescent lamp with its power supply. Switch on the lamp and adjust the distance between the lamp and the solar panel so that maximum area of the solar cell can be illuminated.
3. Record the open circuit voltage ($\mathbf{V_{oc}}$) and the short circuit current ($\mathbf{I_{sc}}$). The product gives the ideal output electrical power of the solar cell for that intensity of light.
4. Vary the potentiometer and record the values of current (**I**) and voltage (**V**) across the solar cell for different load resistances ($\mathbf{R_L}$), keeping the supply voltage to the lamp, distance between lamp and solar cell and hence intensity of incident light energy fixed.
5. Calculate the output electrical powers corresponding to different load resistances and identify the maximum power output and identify its corresponding voltage and current.
6. Plot the I-V characteristics of the solar cell.
7. Calculate the fill factor.

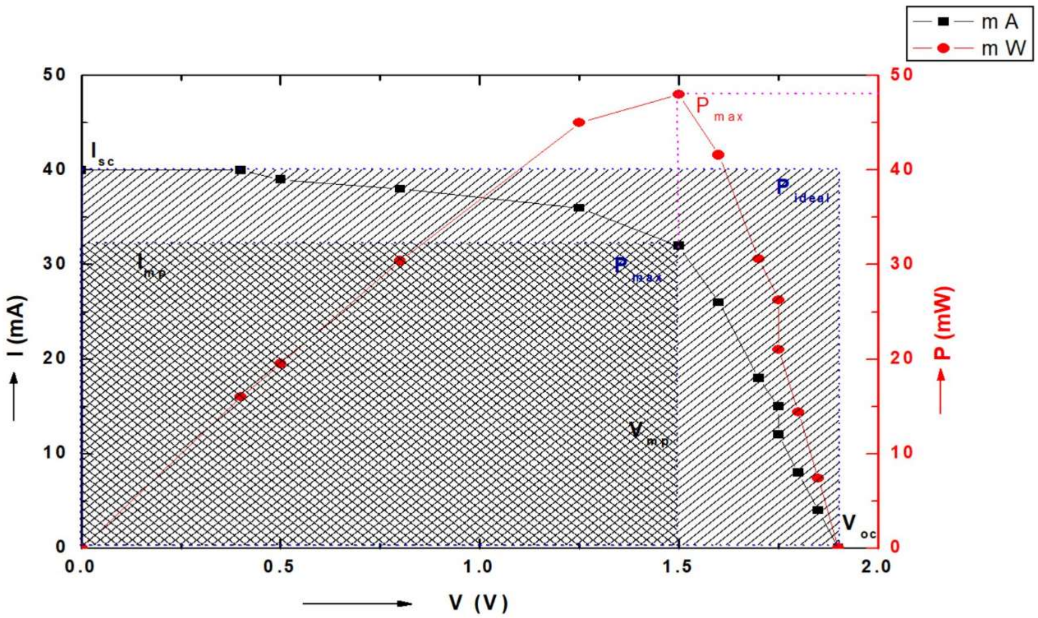

Fig. 2. Typical plot for I-V characteristics of a solar cell.

Table: Experimental readings for I-V characteristics of solar cell.

S. No.	Load Resistance R_L (Ω)	Voltage V (V)	Current I (mA)	Power P = V x I (mW)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

Observations:

Open circuit voltage V_{oc} = ... V,

Short circuit current I_{sc} = ... mA,

Voltage corresponding to the maximum power V_{mp} = ... V and

Current corresponding to the maximum power I_{mp} = ... mA.

Calculations:

Fill Factor, $\mathbf{FF} = \frac{\mathbf{V_{mp} \times I_{mp}}}{\mathbf{V_{oc} \times I_{sc}}} = \frac{\dots\dots \times \dots\dots}{\dots\dots \times \dots\dots} = \dots\dots\dots\dots$.

Result: The I-V characteristics of the solar cell have been studied and the FF is found to be FF = ...