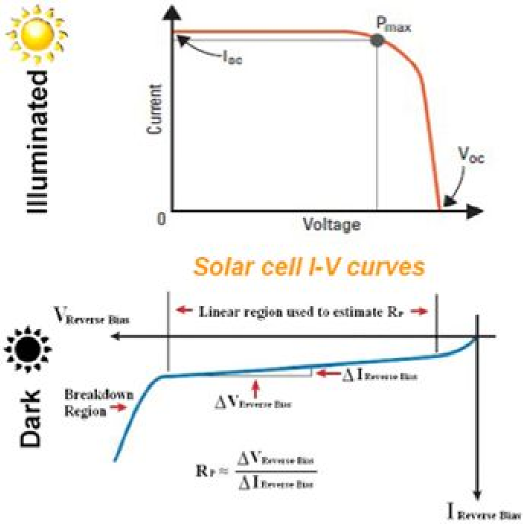
I-V characteristic of a solar cell



Aim: To draw the V-I characteristic of a solar cell under constant illumination and to determine its fill factor.

1. Apparatus required: Solar cell, d.c.voltmeter, d.c.ammeter, resistance box, one way keys, connecting wires.

2. formula used:

(i) Maximum Power = $V_m \times I_m$

(ii) Ideal power = $Voc \times Isc$

(iii) Fill Factor = $\frac{Vm \times Im}{Voc \times Isc}$

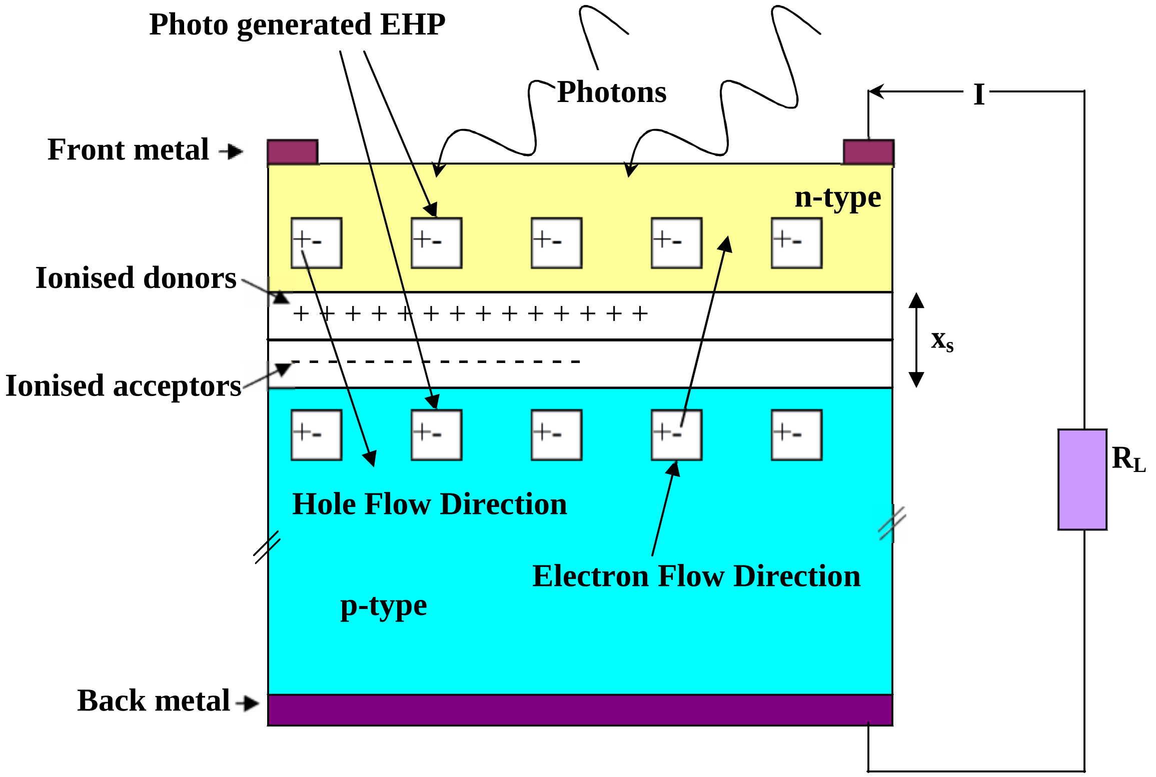
Where,

Vm = Max. Voltage, Im= Max. Current, Voc = Open circuit Voltage, Isc = Short circuit Current.

3. Theory: Solar cell is a device which directly converts light energy to electricity. Becquerel in 1839 discovered this phenomenon of development of a voltage or potential difference under the effect of light (photons). This phenomenon is called Photovoltaic effect. Devices based on this effect are known as **Photovoltaic Cells.** A Solar Cell is a device based on Photovoltaic effect.

Construction

The solar cells generally consists of a p-n junction, where onto its base p-region an n-region is diffused as shown in Fig. above. It can be other way also. The bottom side is totally covered and the front side is partially covered by a metal layers. Metal layers are used to collect all the photo generated carriers generated into the diode materials. Front side is partially covered (≈ 5 - 7 %) to allow more light to incident on the front surface to generate more carriers. The diode materials generally used are semiconductor materials like gallium Arsenide (GaAs), Cadmium Telluride



(CdTe), etc. However, most commonly used materials are Silicon, both in single or multi crystalline form. When a solar cell is exposed to sunlight the photons with energy, hν, greater than E_g of the semiconductor material are absorbed in the cell. In this process a fraction of E_g of photon energy is utilized in creating EHP and the excess energy, $h\nu - E_g$, is dissipated generally in the form of thermal energy given to the crystal. In a pn junction solar cell the incident photons generate EHP in both p and n regions of the junction as shown in Fig. below. The EHP thus produced in the vicinity of the junction and in the space charge region (x_s) at the junction is separated by the strong built-in electric field that exists at the junction. This causes the photo generated electrons of the p-side to flow due to diffusion; they reach the junction and crossover to the n-side. Similarly the photo generated holes of the n-side cross over to the p-side. This accumulation of electrons on n-side and holes on p-side of the junction gives rise to a photo voltage.

► The photo voltage attains a maximum value when there is infinitely large load across the cell such that the output current of the cell is zero. This is the maximum photo voltage and is known as the **Open Circuit Voltage (V_{oc}).**

If a finite load resistance, R_L, is connected across the cell, current flows through it and there is a voltage drop also across the load.

► When the load connected across the diode terminals is zero, the current is maximum and is known as **Short Circuit Current, I_{sc}.**

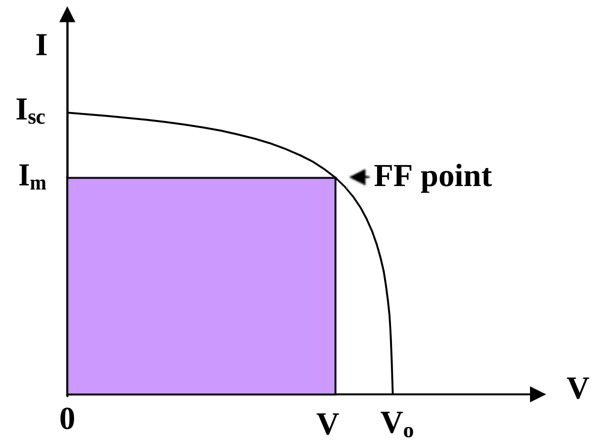
For a finite value of R_L the current continues to flow in the circuit as long as the solar cell is exposed to sunlight, its magnitude being higher for a higher intensity of light.

The photocurrent, I, which flows through the solar cell and the load is given by

$$I = I_{sc} - I_d \text{ ---------------- (1). Here, } I_d = I_0\left[e^{\frac{V+IR_s}{n\kappa T}} - 1\right] - \frac{V+IR_s}{R_{sh}} \text{ ---- (2)}$$

Here, junction voltage, $V_j = V + IR_s$, and V is the voltage developed across the load R_L, I_d and I_0 are the diode and reverse saturation current of the cell respectively, n is diode ideality factor. Here R_s and R_{sh} are the series and shunt resistances of the cell respectively. The ideal values of R_s and R_{sh} are zero and infinite respectively. However, in all practical solar cells it is difficult to achieve these values.

Under open circuit condition V_{oc} can be expressed as $V_{oc} = \frac{n\kappa T}{q} \ln\left[\frac{I_{sc}}{I_0} + 1\right]$ ---------------------- (3)



The condition of maximum power is $\frac{d(IV)}{dV} = 0$ --------- (4). Eqn. (3) in conjunction with Eqn. (1) gives the value of maximum power output, P_m, under ideal condition (i.e., $R_s = 0$and $R_{sh} = \alpha$) as $P_m = I_m V_m$ ---------------------- (5). Here, I_m and V_m are the values current and voltage of the cell at maximum power point. The curve factor (CF) or Fill Factor (FF) of the illuminated I-V characteristics of the cell is defined as,

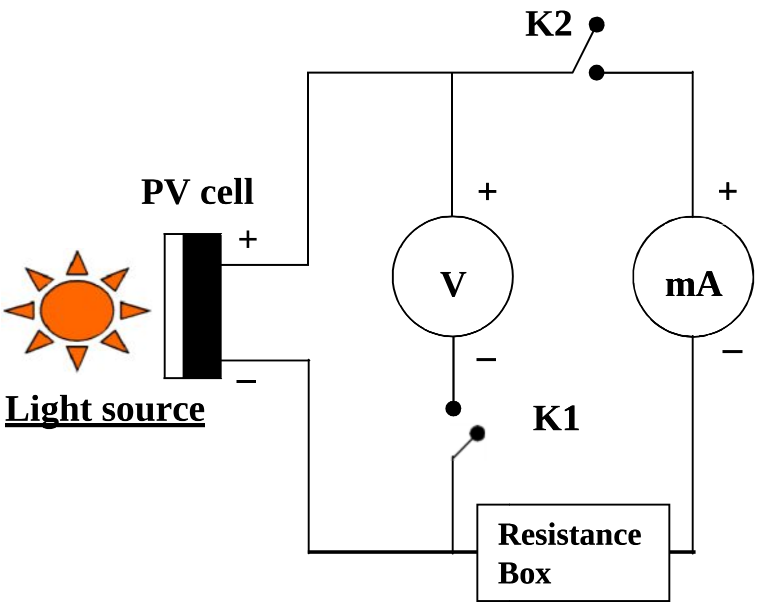
$$FF = \frac{P_m}{I_{sc} V_{oc}} \text{ ------------- (6)}$$

FF is a measure of how squarish is the I-V characteristics of the cell. However, FF is always less than 1. Larger the value of FF more squarish is the I-V characteristics of the cell. Increase in R_s and decrease in R_{sh} results in degradation of FF. FF basically denotes the maximum power rectangle inside the curve as also clear from the above Fig. An ideal solar cell characteristic curve lays in fourth quadrant due to the flow of the minority carriers only and hence is negative. However, for simplicity we draw it on the first quadrant as shown in Fig. above.

4. Procedure:

(i). Keep the solar cell under light so that the light falls normally on it.
(ii). Make circuit connections as shown in Fig. next.

(iii). Switch on the light source & close key K1. Note the reading of voltmeter. This is V_{oc}.
(iv). Open K1 & and close K2. Make the resistance in resistance box as zero and note the reading in ammeter. This is I_{sc}.
(v). Now close both K1 & K2. Introduce resistance from resistance box in steps and note the voltmeter and ammeter readings for each value of resistances.
(vi). Remove K1 & K2 and switch of the light source.



5. Observations:

Open circuit voltage (V_{oc}) = Volts; Short circuit current (I_{sc}) = mA

Sr. No.	Resistance (Ω)	Readings of		Power output, VI (mW)
		Voltmeter, V (V)	Ammeter, I (mA)	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

6. Results :

(i). Draw the graph between V along X-axis and I along Y-axis.

(ii). Mark the point at which power output, obtained from previous table, is maximum. This is the fill factor point.

(iii). <u>Determination of the fill factor.</u>

Value of voltage at maximum power output point from the table = V_m = V.

Value of current at maximum power output point from the table = I_m = mA.

So, Fill factor = $\frac{V_m \times I_m}{V_{oc} \times I_{sc}}$ = .

7. Precautions:

(i). The light from source should fall normally on the cell.

(ii). Light exposure time should be optimum as over exposure of light will heat the cell, which subsequently degrade the cell performance.

<u>VIVA-VOCE</u>

Q1. 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.

Q 2. Define fill factor.

Ans. It is the ratio of Maximum useful power to the ideal power.

$$\text{Fill Factor (FF)} = \frac{Vm \times Im}{Voc \times Isc}$$

Q 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 a electron-hole pair. If the energy is less than the band gap energy, it produce excitation.

Q 4. What is the conversion efficiency range of a silicon cell?

Ans. 10 to 15 %

Q 5. What is the range of fill factor for silicon?

Ans. 0.65 to 0.80