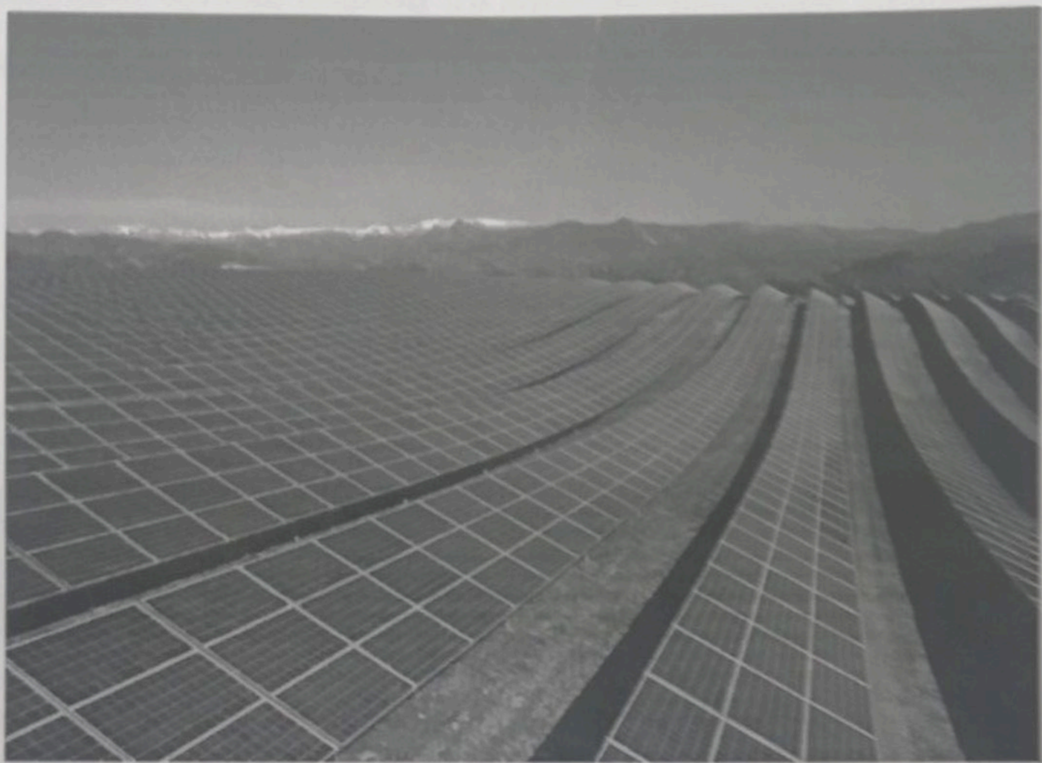
Aditya Bandgar
Div 16
116013

MIT-WPU
Dr. Vishwanath Karad
MIT WORLD PEACE UNIVERSITY | PUNE

Preamble for Experiment 8: Characteristics of Solar Photovoltaic Cell



World's largest Solar Photovoltaic Power Plant is situated in Madhya Pradesh, India. (750 MW, 1,500 hectare and Rs. 45 billion). What is Solar Photovoltaic cell? and what are it's characteristics?.

Solar cell was invented by Gerald Pearson

 Gerald Pearson (left) with his colleagues in Bell lab	**Gerald Pearson (1905-1987):** He was an American Physicist. He obtained degree from Stanford University. Then he joined Bell laboratories as a Physicist. There he earned several patents while working on PN junctions and transistors. There was no photovoltaic industry before 1954. In 1954, along with his colleagues Daryl Chapin and Calvin Fuller, Pearson invented the first silicon solar cell. The first solar cell had an efficiency of only 6%, however due to intense research thereafter, the efficiency increased to 10 %. After 1960, Pearson joined Stanford University as a Professor of Physics

Pledge

I solemnly affirm that I am presenting this journal based on my own experimental work. I have neither copied the observations, calculations, graphs and results from others nor given it to others for copying.

Signature of the student

Experiment 7: Characteristics of Solar Photovoltaic Cell

Aim: To plot I-V characteristics of solar cell, to determine its fill factor and corresponding optimum load

Apparatus: Solar cell/solar panel, current and voltmeters (OR DMM), variable load and source of light

Significance of the experiment: *Solar cell is a specially designed PN junction which converts light in to electrical power. The ability of the solar cell to deliver optimum power to the optimized load is signified in terms of it's fill factor. The present experiment aims at calculation of the fill factor and corresponding optimum load for a given solar cell.*

Theory: Solar cell is a specially designed PN junction diode that converts light into electrical power. This conversion occurs in three stages. When the PN junction is exposed to light, electron hole pairs are generated in P and N regions. These are then separated across opposite electrodes due to emf at the junction. (refer Fig.7.1). The separated carriers accumulate across the metal contacts and thus generate a potential difference (p.d). This p.d. can drive the optically excited minority carriers in circuit. Thus solar cell, when exposed to light, behaves as a battery that can deliver power to a load. The typical voltage and current from one junction is around 0.6 volts and a few micoramp, however this can be increased by cascading the solar cells in series and parallel (solar panels). Solar cells generate electricity from inexhaustible, freely available sunlight and without pollution, without accidents and need less maintenance. Further, an option of decentralized production can decrease transmission losses. However the low efficiency (10%), high production cost and dependence on sunlight limit its applications to remote areas (such as satellites and villages in deserts, forests) & low power accessories (such as calculators, wrist watches, street lights and solar water pumps). If efficiency is improved, solar power may find uses in solar automobiles, solar houses and many other areas.

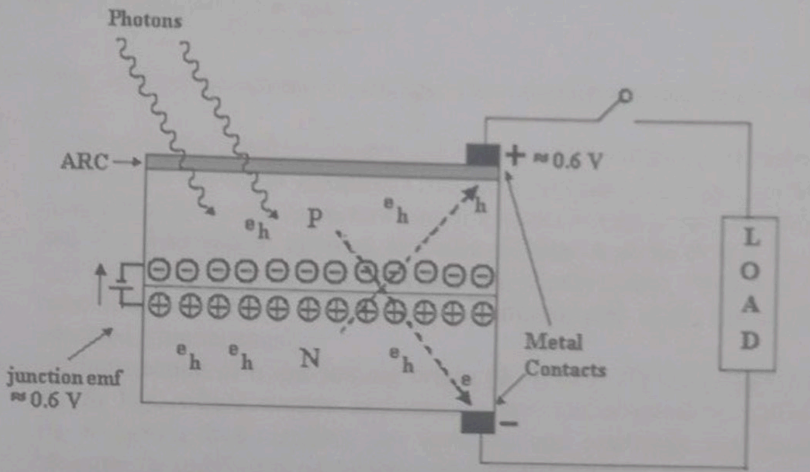


Fig. (7.1): Solar cell and its working

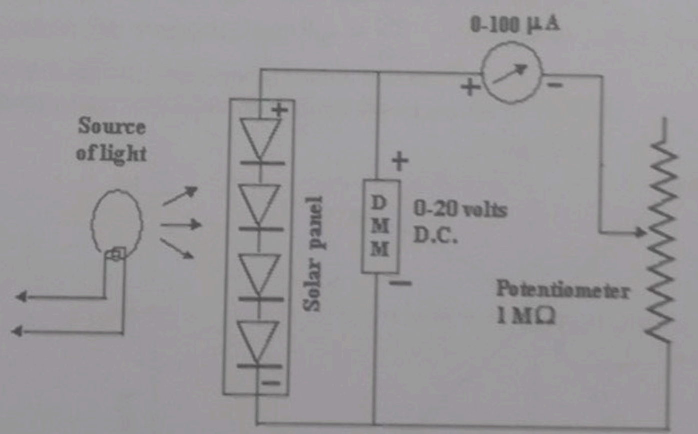


Figure (7.2): Circuit diagram

Procedure:

1. Connect the circuit as shown in the diagram (Fig.8.2) and get it checked. Connect DMM as a 0-20 voltmeter in parallel and DMM and 0-200 μA in series across the 1 MΩ variable load.
2. Make the light source ON and keep it to optimum intensity.
3. Take as many as possible current and voltage readings by varying the load. The readings corresponding to minimum and maximum load must be taken. Tabulate your observations as per table 8.1

4. Plot the graph of current Vs voltage. This represents characteristics of solar cell (refer Fig 8.3)
5. Extrapolate the graph on current and voltage axis. While extrapolating the curve keep the slope same. Calculate I_{SC}(Short circuit current) and V_{OC}(Open circuit voltage) from the intercept of the curve on current and voltage axis respectively. Draw perpendiculars at I_{SC} and V_{OC}. Intersection of these two lines defines a point P_I (I_{SC}, V_{OC}). The product $P_I = I_{SC} \times V_{OC}$ signifies ideal but unachievable power (refer Fig.8.3). The ideal power is unachievable because short circuit condition and open circuit condition cannot be obtained simultaneously.
6. An intersection of a line joining origin (0, 0) to P_I (I_{SC}, V_{OC}) on the curve gives a point, P_W (I_W, V_W), where current and voltage are simultaneously optimum. The product $P_W = I_W \times V_W$ thus signifies the optimum and realizable and hence workable power. Measure I_W and V_W and calculate workable power (P_W)
7. Calculate the fill factor $\left(f = \frac{P_W}{P_I} \times 100\ \%\right)$. The fill factor signifies the extent to which workable power is close to ideal power. Alternatively, it signifies the extent to which workable power rectangle 'fills' the ideal power rectangle.
8. Calculate the workable load $R_W = \frac{V_W}{I_W}$. R_W signifies the workable load at which solar cell can deliver optimum/workable power.
9. Tabulate your calculations and results as per the table (8.2)

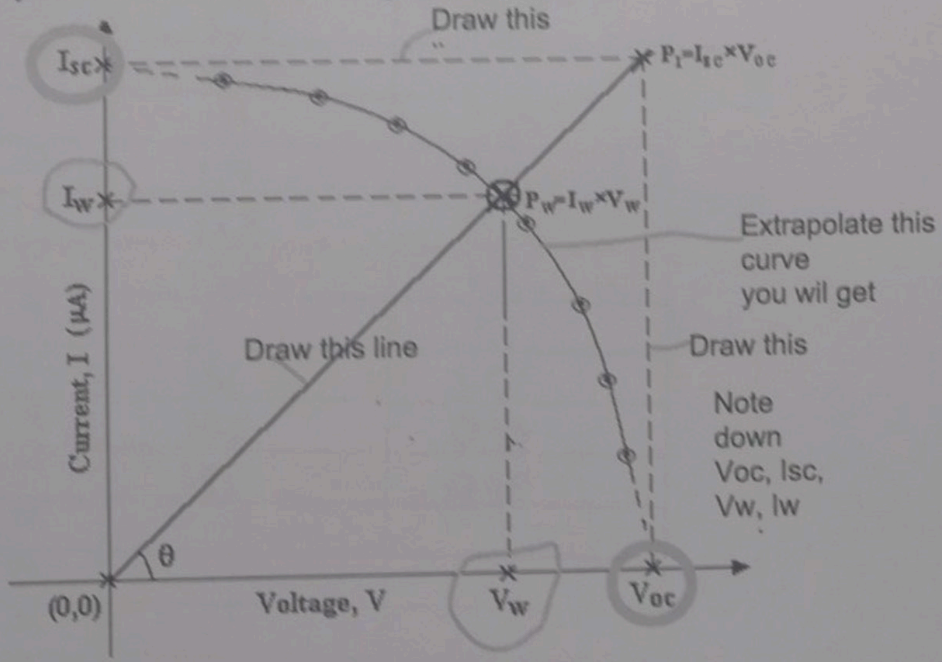


Figure (7.3): Characteristics of solar cell and calculations

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ROUGH WORK

Table 7.1 Observations

Sr. No.	Current (μA)	Voltage (volts)
1	(Minimum)=0	(Maximum)=2.35
2	8	2.21
3	19.4	2.12
4	24.5	2.02
5	36.3	1.98
6	45.8	1.87
7	58.7	1.79
8	66.5	1.72
9	78.2	1.63
10	88.7	1.59
11	97.8	1.47
12	111	1.39
13	119	1.31
14	129	1.27
15	138.5	1.22
16	151.1	1.1
17	158.2	1.01
18	168	0.84
19	181	0.46
20		
21		
22		
23		
24		
25	(Maximum)	(Minimum)

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Table 7.2: Calculations and results

Sr. No.	Quantity	Symbol and Formula	Value	Unit
1	Short circuit current	I_{SC}	190	µA
2	Open circuit voltage	V_{OC}	2.83	Volts
3	Ideal power	$P_I = I_{SC} \times V_{OC}$	537.7	µW
4	Workable current	I_W	112	µA
5	Workable voltage	V_W	1.4	Volts
6	Workable power	$P_W = I_W \times V_W$	156.8	µW
7	Fill factor	$F = \frac{P_W}{P_I} \times 100\,\%$	29.16	%
8	Workable load	$R_W = \frac{V_W}{I_W \times 10^{-6}}\,\Omega = \cdots k\Omega$	12500	kΩ

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FAIR WORK

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9	88.7	1.59
10	97.8	1.47
11	111	1.39
12	119	1.31
13	129	1.27
14	138.5	1.22
15	151.1	1.1
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25	(Maximum)	(Minimum)

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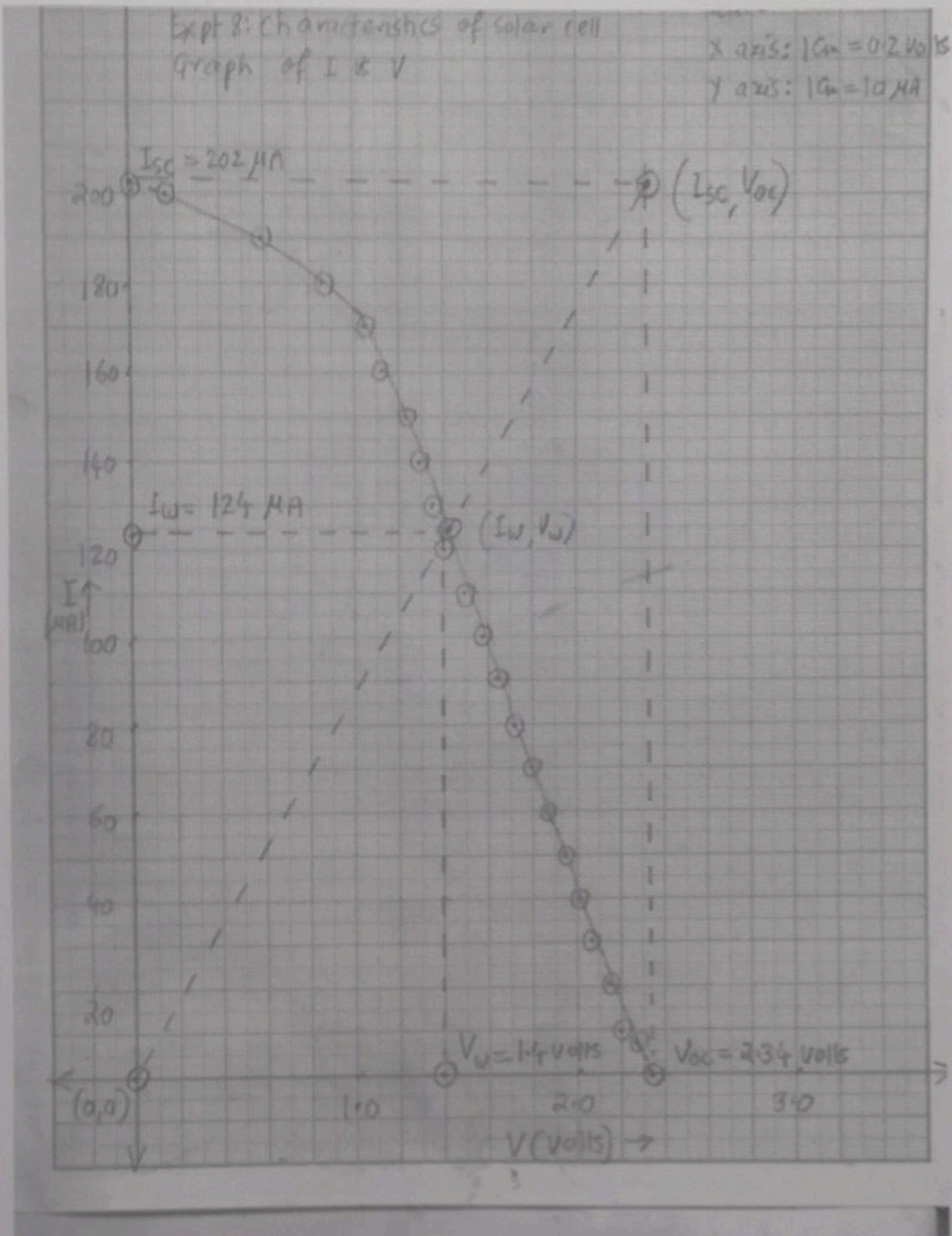
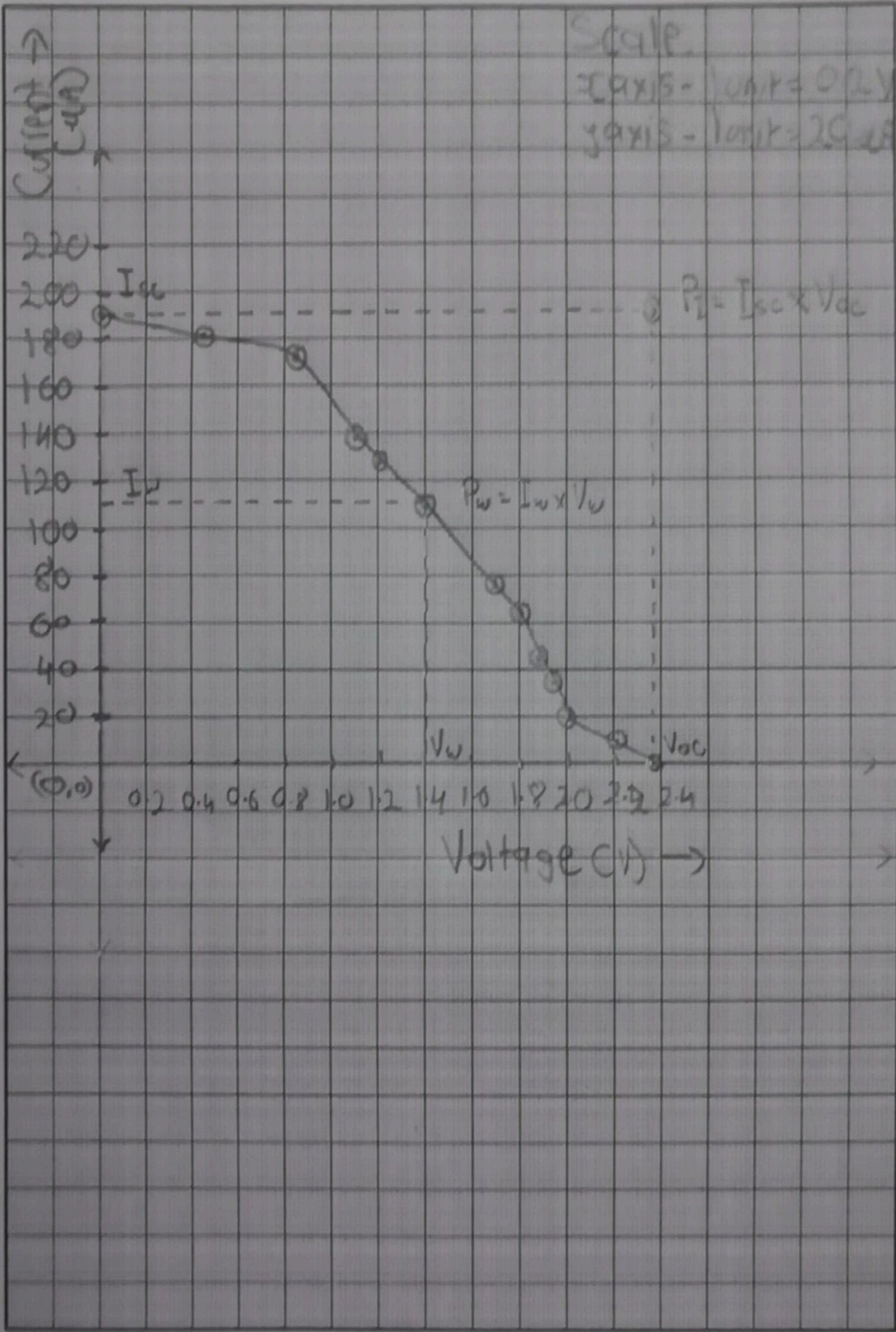
Viva Voce

1. Why efficiency of solar cells is limited to 10% only?
2. Does solar cell work on minority carriers or majority carriers?
3. What is the role of electric field across the PN junction in the action of solar cell?
4. Explain what you mean by I_{SC} i.e. short circuit current. Why I_{SC} has to be obtained by extrapolation method only? Why cannot it be measured in the experiment?
5. Explain what you understand by V_{OC} i.e. open circuit voltage. Why V_{OC} has to be obtained by extrapolation? Why it cannot be measured in the experiment?
6. Why ideal power is practically unachievable?
7. Why workable power cannot be extracted by a small or large load?
8. Why fill factor can never reach to 100%?
9. How does fill factor of a solar cell differ from its' efficiency?
10. Does fill factor signify the quality of the solar cell itself or the load or both?
11. What do you mean by R_W i.e. workable load? What is it's significance?
12. Why solar cell cannot deliver large power when workload is too large or too small?
13. Solar cell is basically a PN junction diode. Why, then, the characteristics of solar cell does not appear like that of diode?
14. Give any two advantages and any two disadvantages of solar cell.
15. Give any five applications of solar cell.

Model Graph for Expt. 7, Solar Photovoltaic cell

This Model Graph is only for cross-checking your graph with its nature and style of presentation. As such, your Graph must be based on your own observations and calculations. Only formatting and presentation needs to be as per the Model Graph.





Scale
x axis - 1 unit = 0.2 V
y axis - 1 unit = 20 mA
Current (mA)
I_{sc}
I_m
$P_T = I_{sc} \times V_{oc}$
$P_m = I_m \times V_m$
V_m
V_{oc}
(0,0)
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
20 40 60 80 100 120 140 160 180 200 220
Voltage (V)

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My Understanding of the Experiment

(Not exceeding 5 to 6 lines)

In this experiment we learnt how to find the fill factor of a solar cell and optimum load of a solar cell by observing Current and voltage characterstics of the given solar cell. We also learnt that we con find out ideal power, workable current, workable voltage and other features of the photovoltic cell. We ~~as~~also came to know that solar cells convert light into electricity because they ~~have a spe~~ are a specially designed P-N junction diode.