Power Systems Lab

Experiment - 5

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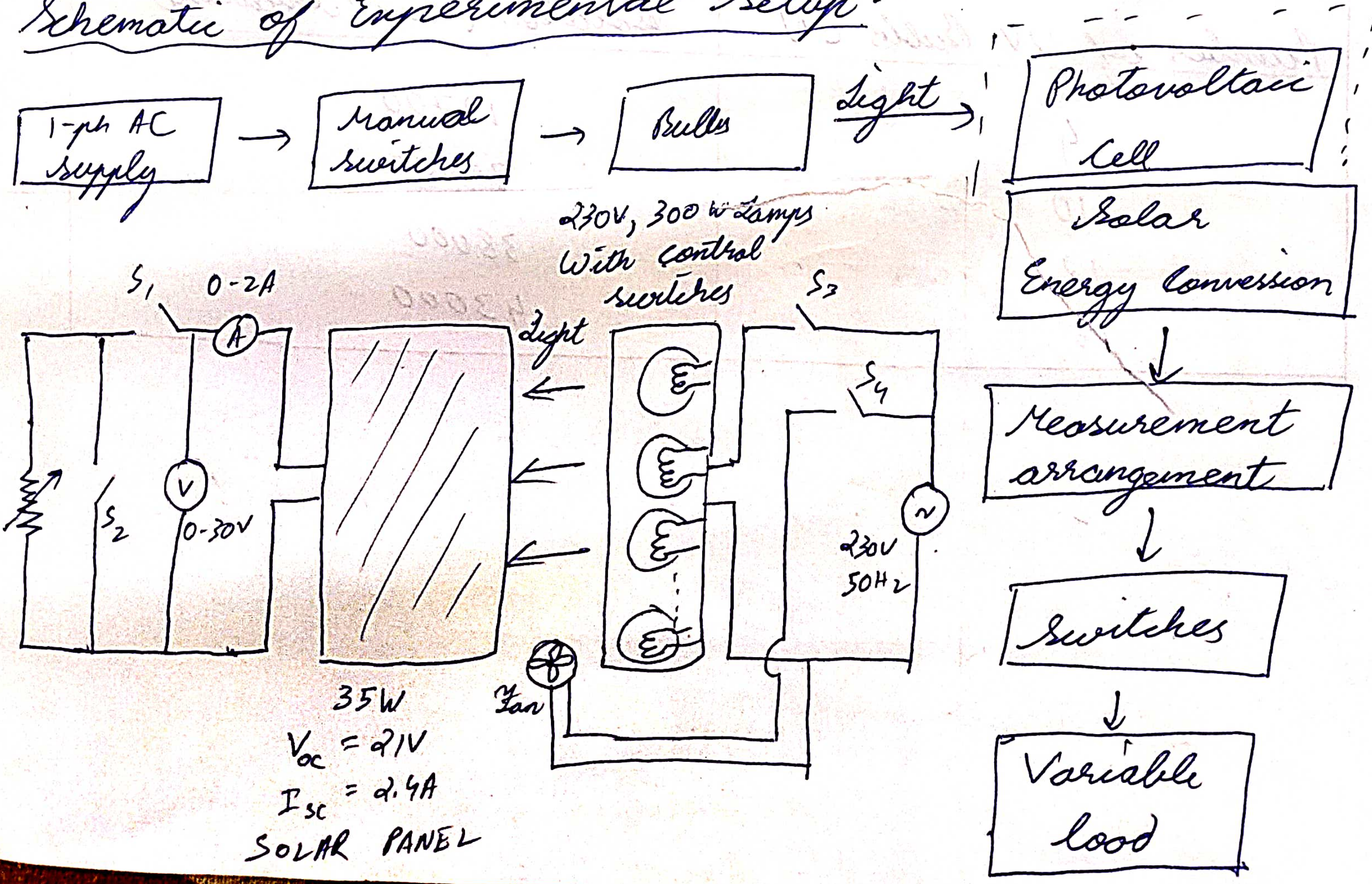
Objectives of the experiment :-

1) Study of solar PV energy conversion system (SPVECS) to understand its basic characteristics and working principle.
2) To familiarise with solar PV based experimental set-up.
3) To understand experimental procedure for measurement and observation
4) To realize the experimental cases for characterisation under 3 different study conditions -
   - Varying the load
   - Under different intensity of light
   - Under dark conditions

Schematic of Experimental Setup :-



Components used in experimental set-up:-

1) Ammeter
2) Variable load
3) Multimeter in voltmeter mode
4) Switches
5) SPVECS
6) ~~Lux m~~ Lux meter
7) Regulated DC power supply
8) Cooling fan
9) Solar Emulator
10) Solar PV panel

Experimental cases:-

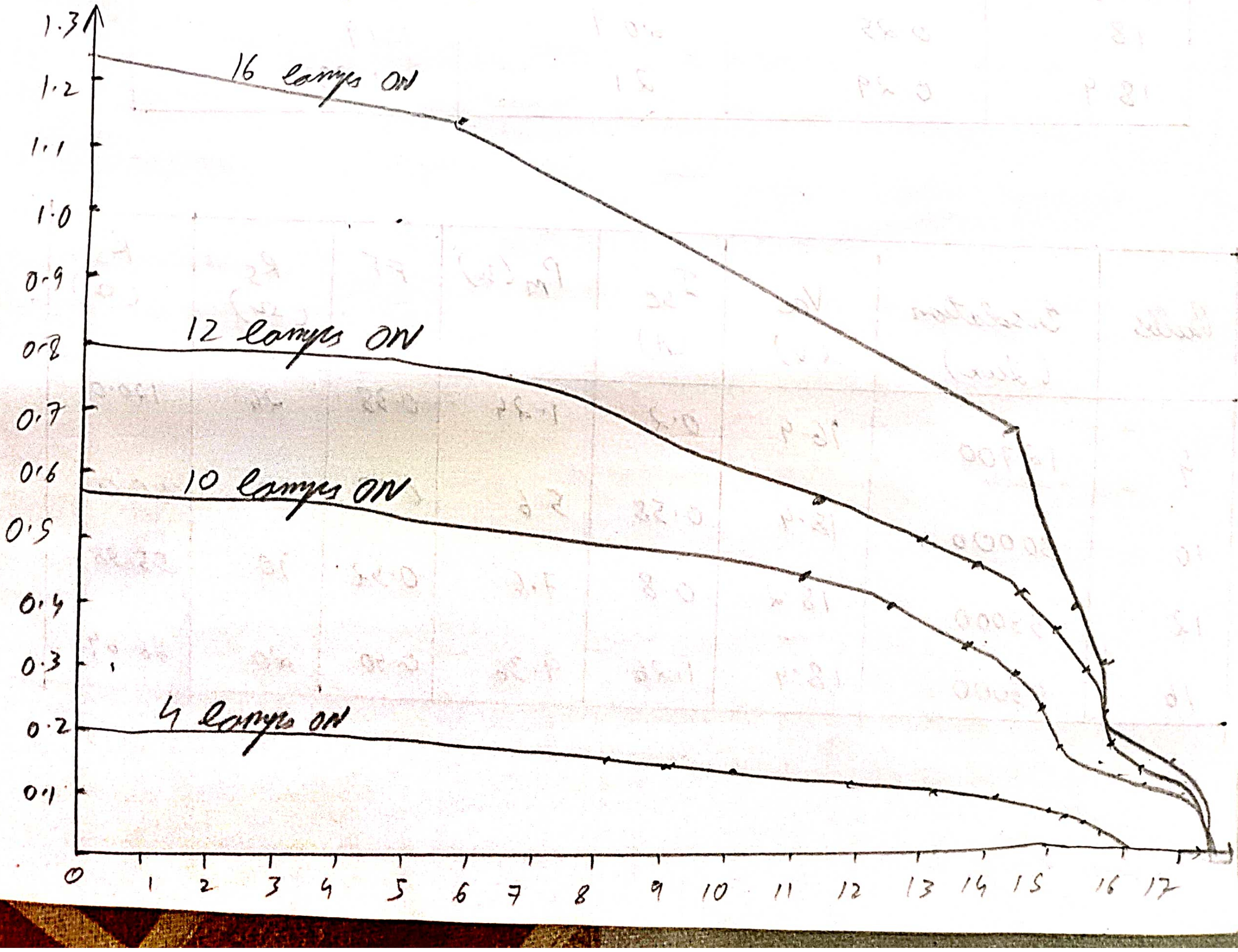
1) Case 1 (Load (R-ohm) variation)

Observation table:-

Number of UV Bulbs ON	Insolation (lux) Available
4	12700
10	30000
12	38000
16	43000

4 lamps ON		10 lamps ON		12 lamps ON		16 lamps ON	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
16.4 (V_{oc})	0	18.4 (V_{oc})	0	18.2 (V_{oc})	0	18.4 (V_{oc})	0
14.8	0.06	18	0.08	18	0.08	18	0.08
14.4	0.08	17.6	0.09	17.6	0.12	17.6	0.1
14	0.08	17.2	0.12	17.5	0.14	17.2	0.14
12.9	0.09	16.9	0.14	17.2	0.18	16.8	0.26
12.4	0.1	16.8	0.16	17	0.2	16.6	0.28
12	0.1	16.6	0.2	16.8	0.22	16.5	0.3
11.2	0.1	16.5	0.22	16.6	0.28	16.4	0.34
10 (V_m)	0.12	16.4	0.24	16.4	0.36	16.2	0.4
6.4	0.14	15.4	0.34	16	0.4	15.6	0.56
4	0.16	14 (V_m)	0.4 (I_m)	13 (V_m)	0.58 (I_m)	15.6 (V_m)	0.6 (I_m)
1	0.18	8.2	0.5	5.6	0.74	7.2	1.15
0	0.2 (I_{sc})	0	0.58 (I_{sc})	0	0.8 (I_{sc})	0	1.26 (I_{sc})

I-V graph of solar panel :-

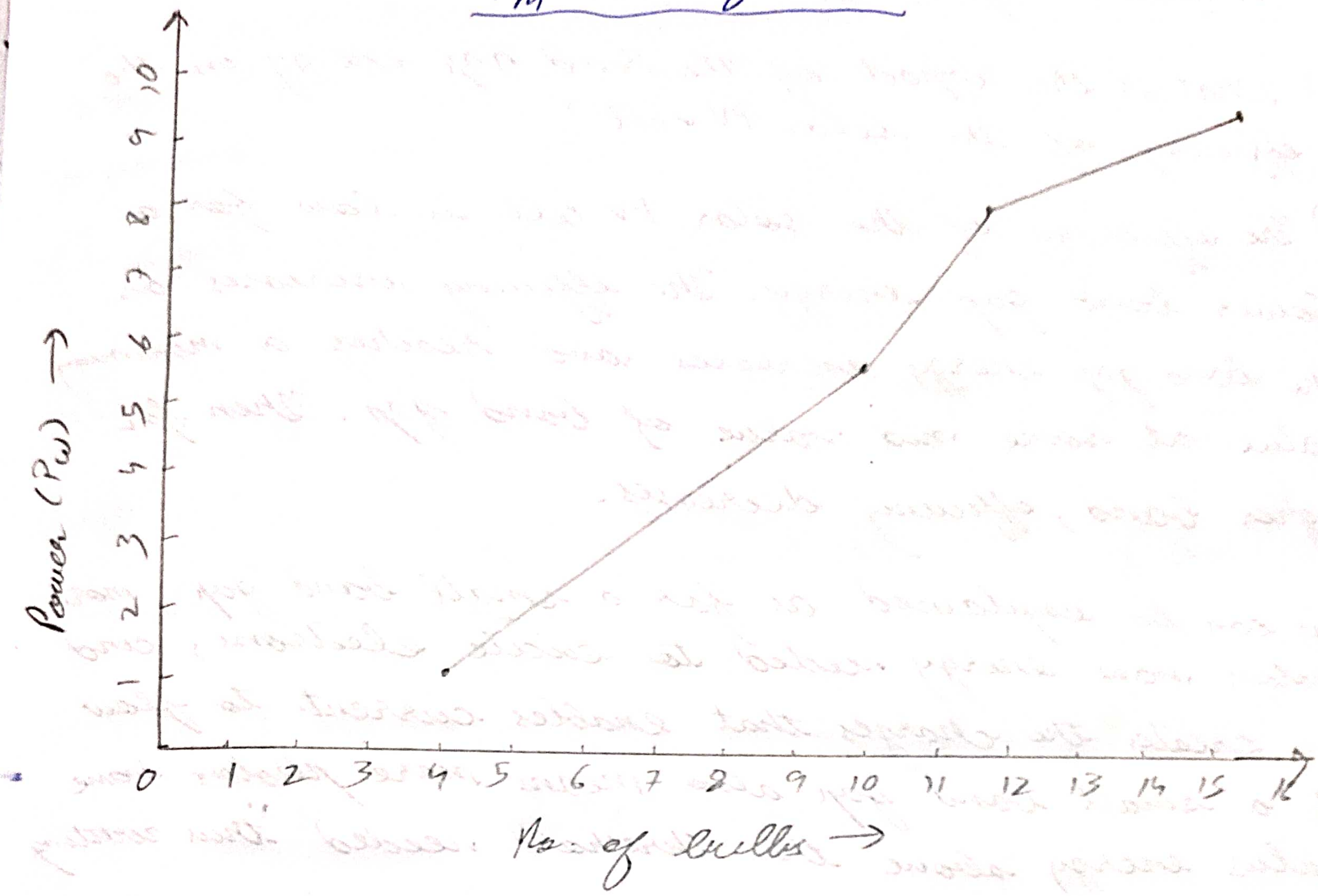


2) Case 2 (Dark Test)

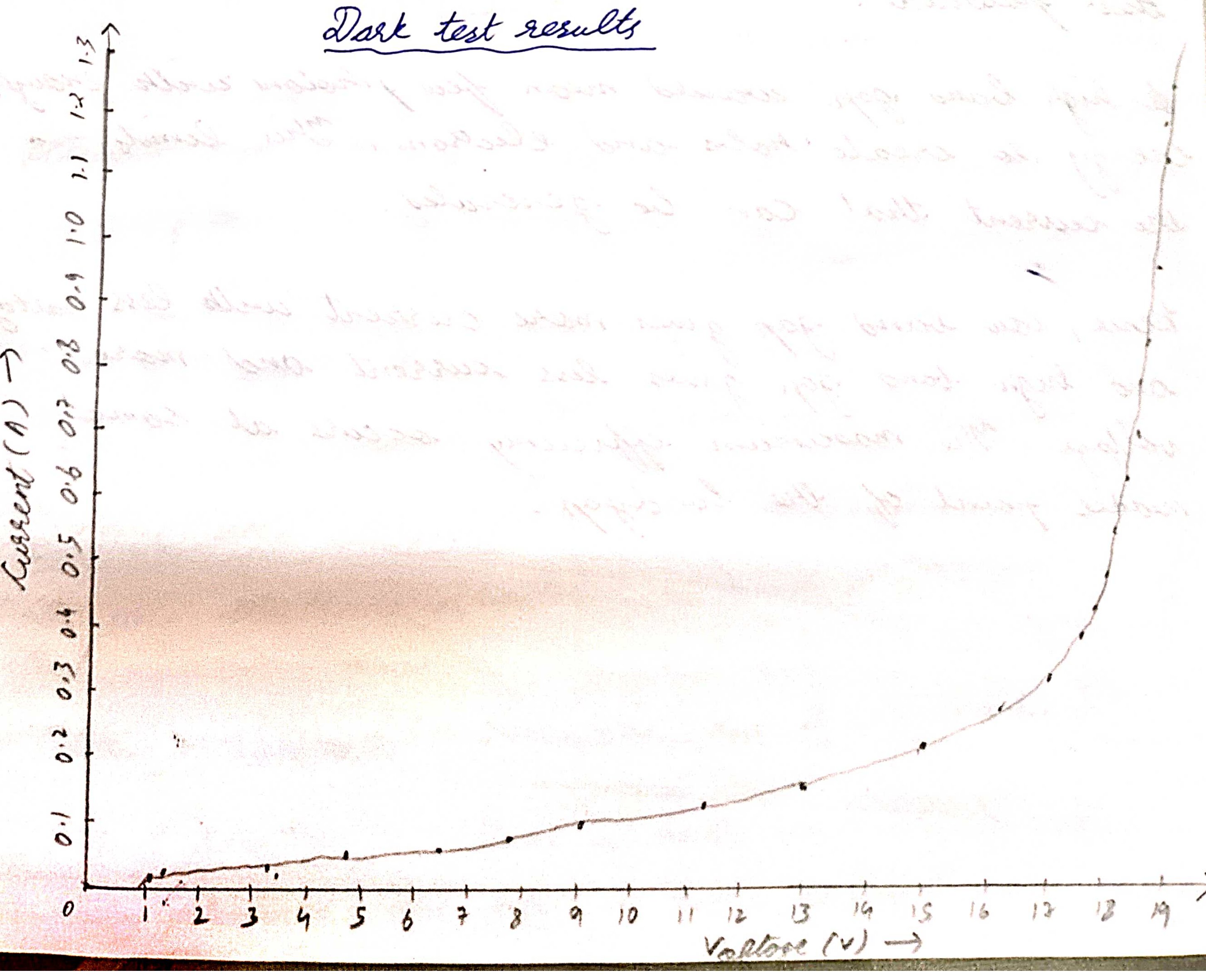
Voltage (V)	Current (A)	Voltage (V)	Current (A)
0.18	0	18.7	0.34
1.35	0	19	0.4
1.36	0.01	19.4	0.49
3.19	0.02	19.5	0.51
4.8	0.03	19.6	0.56
6.35	0.04	19.7	0.58
7.73	0.05	19.8	0.63
9.09	0.06	19.9	0.65
11.4	0.08	20	0.7
13.3	0.1	20.2	0.82
15.2	0.13	20.4	0.88
16.4	0.16	20.6	0.99
17.3	0.2	20.8	1.14
18	0.25	20.9	1.19
18.4	0.29	21	1.28

Bulbs	Insolation (Lux)	Voc (V)	I_{SC} (A)	P_M (W)	FF	R_S (Ω)	R_{SH} (Ω)
4	12700	16.4	0.2	1.24	0.38	26	120.0
10	30000	18.4	0.58	5.6	0.52	40	80.00
12	38000	18.2	0.8	7.6	0.52	10	55.38
16	43000	18.4	1.26	9.36	0.40	20	66.69

P_m vs no. of bulbs



Dark test results



Discussion questions:-

1) What is the impact of the Band gap energy on the efficiency of the solar PV cell?

A) The efficiency of the solar PV cell is low for a lower band-gap energy. The efficiency increases as the band gap energy increases and reaches a maximum value at some mid-value of band gap. Then for higher band, efficiency decreases.

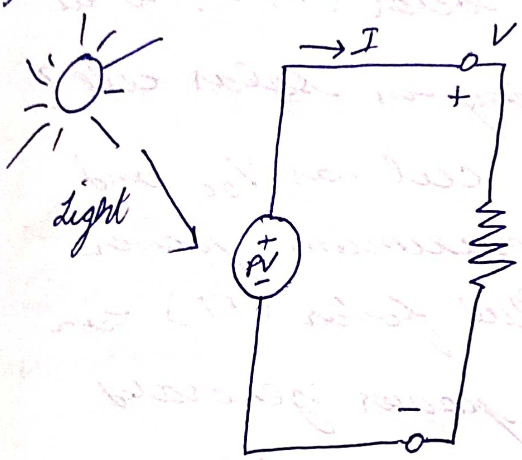
This can be explained as for a small band gap, more photons have energy needed to excite electrons, and this creates the charges that enables current to flow. But a small band gap also means more photons have surplus energy above the threshold needed thus wasting their potential.

A high band gap would mean few photons with enough energy to create holes and electrons. This limits the current that can be generated.

Hence, low band gap gives more current with less voltage and high band gap gives less current and more voltage. The maximum efficiency occurs at some middle point of the bandgap.

2) Draw the generic and accurate equivalent circuit for a solar PV cell with equation for current and voltage. Also explain the significance of all four components in that circuit.

A) Simple Equivalent circuit →



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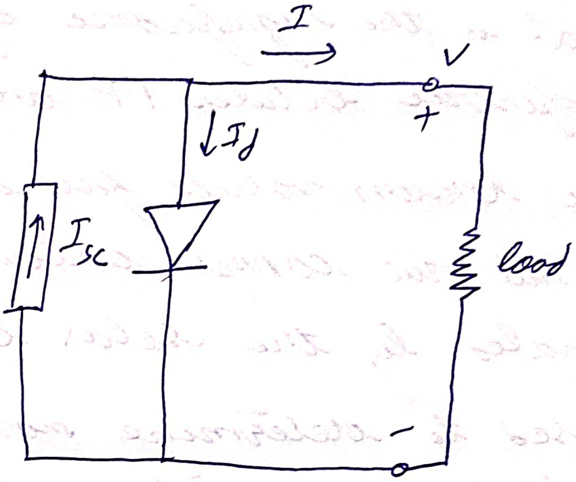
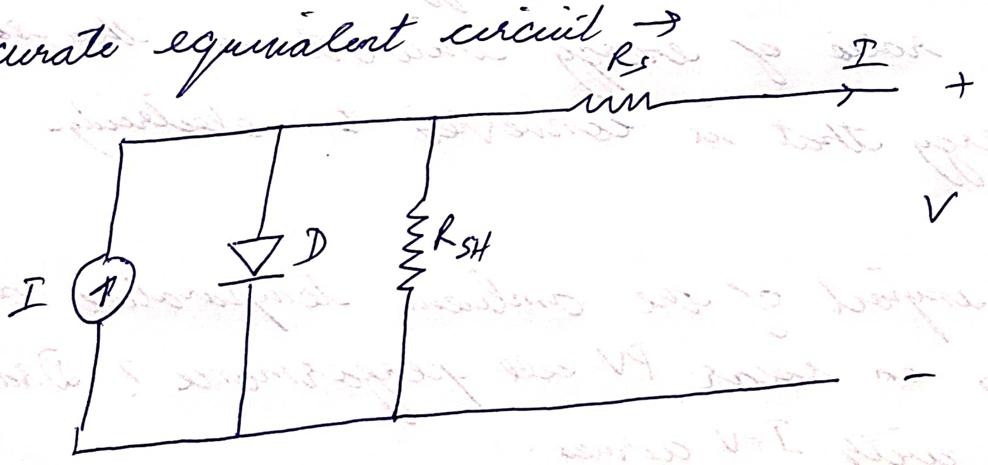


$$I = I_{SC} - I_0\left(e^{qV/kT} - 1\right)$$

$$V_{OC} = \frac{kT}{q} \ln\left(\frac{I_{SC}}{I_0} + 1\right)$$

Accurate equivalent circuit →



I_L (Photovoltaic current) :- Represents current due to holes and electrons produced due to photoelectric effect.

R_s (Series resistance) :- Resistance due to PV material.

R_{SH} (Shunt resistance) :- Some of holes and electrons recombine after being produced. This leads to some current not flowing through load. This is represented as shunt resistance

D(diode) :- Represents the reverse path through which current flows in opposite direction in PV cell as voltage difference is created between PV cell terminal.

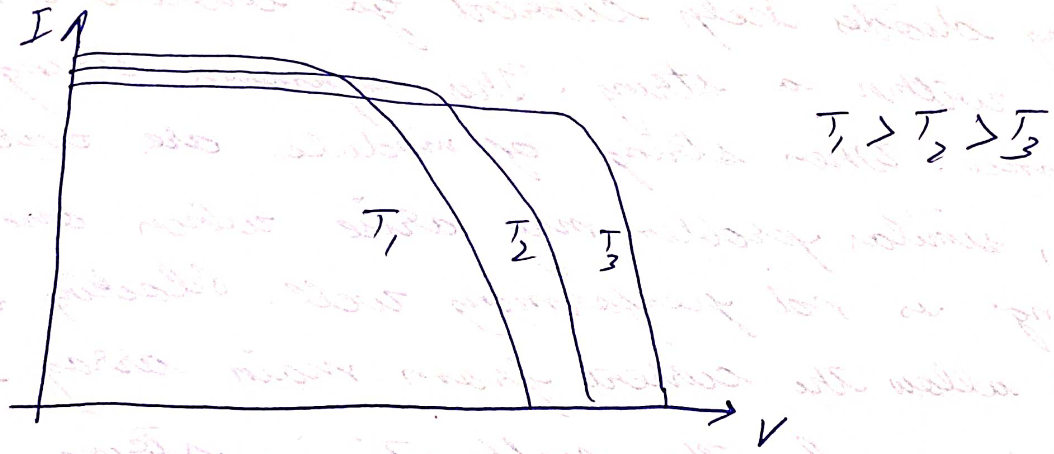
3) What is the significance of Fill Factor (FF)? What is difference between FF and Efficiency in solar cell?

A) The known values for a solar cell as V_{oc} and I_{sc}. But we cannot calculate maximum power generated by the solar cell. Fill factor (FF) can be used to determine maximum power generated and also gives us idea about I-V characteristics of the solar cell.

Fill factor is used to determine the maximum power generated by solar cell, whereas efficiency is the measure of the ratio of energy incident on the solar cell to the energy that is converted to electricity.

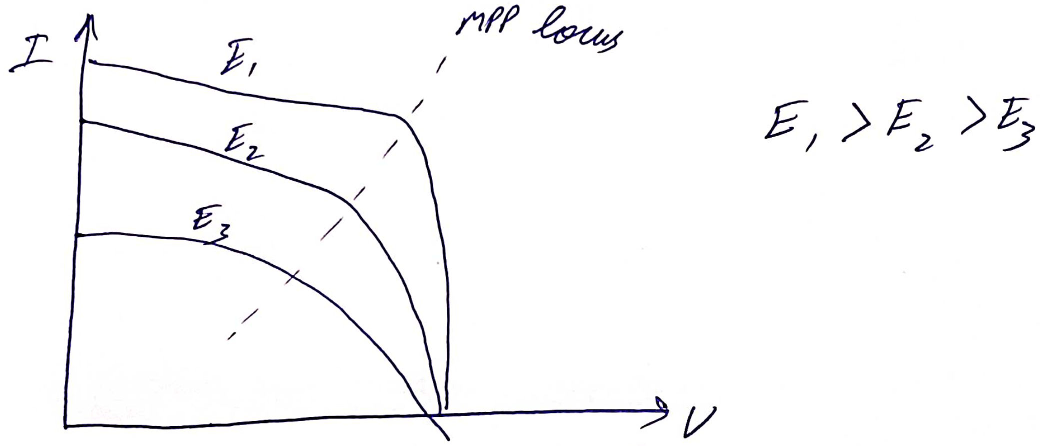
4) What is the impact of the ambient temperature and solar radiation on solar PV cell performance? Draw and explain it with I-V curves.

A) As the ambient temperature increases, V_{oc} decreases substantially, but I_{sc} increases slightly. Hence, MPP slides slightly upwards and towards left with decrease in maximum power. As temperature increases, max^{m} power generated by solar cell decreases.



I-V variation with ambient temperature

As insolation drops, I_{sc} drops in direct proportion. This also reduces V_{oc}. But the change in V_{oc} with insolation is moderate.



I-V variation with insolation change.

5) What is the purpose of bypass diode and blocking diode in a solar PV system?

A.1) Bypass diodes can be used to solve the voltage drop problem in cells that are in shade. When a solar cell is in the sun, voltage across the cell increases and bypass diode is cutoff.

When solar cell is in shade, there would be a voltage drop if the cell conducted any current and would turn on the bypass diode. This diverts the current flow through that diode.

2) Blocking diodes help current go around a shaded module within a string. This improves string performance. When strings of modules are wired in parallel, similar problem may arise when one of the strings is not performing well. Blocking diode does not allow the current from main array to be withdrawn by the malfunctioning string.