Name: PRELIM SOLUTION DRAFT I.D.: _____

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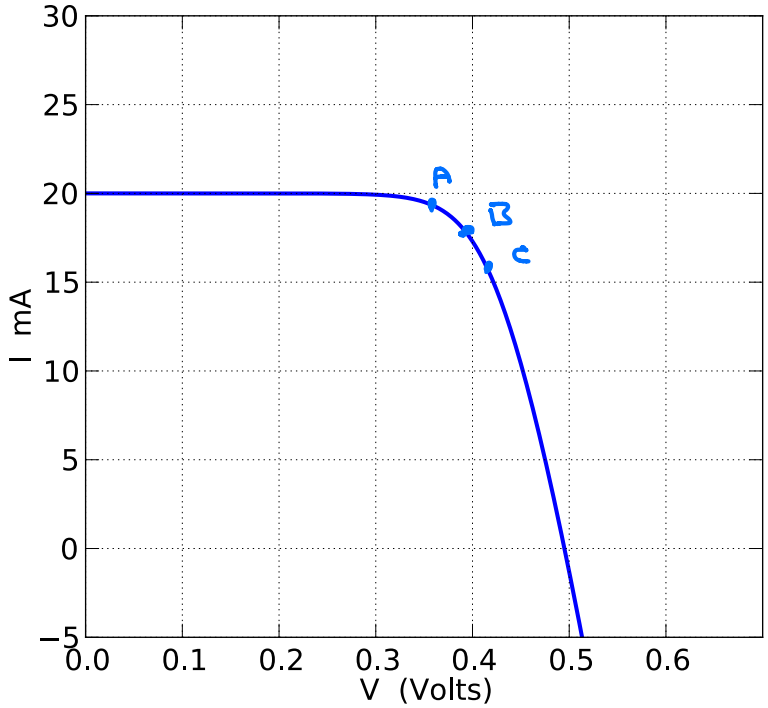
2. The IV characteristic of a photovoltaic cell is shown. Estimate the fill factor and the series resistance.



Need to find the maximum power point.

Method 1

Pick a few points and interate. At the points shown

A: $P = 0.35 \times 19 = 6.64$ mW

B: $P = 0.39 \times 17.5 = 6.83$ ← close

C: $P = 0.42 \times 16 = 6.72$

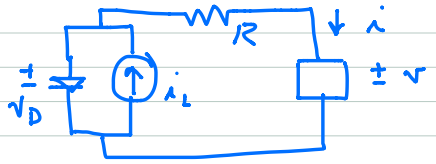
$$FF = \frac{P_{max}}{V_{oc} \cdot I_{sc}} = \frac{6.83}{(0.495)\,20} = 0.69$$

Series R:

A rough estimate is

$$\frac{1}{R} = -\frac{dI}{dV}\bigg|_{V_{oc}} = \frac{10}{0.05} \Rightarrow R = 5\ \Omega$$

This is too high. A better estimate is on next page.



$$v_D - v = iR$$

$$i = i_L - i_0\left(e^{v_D/V_T} - 1\right)$$

$$i = i_L - i_0\left(e^{(v+iR)/V_T} - 1\right)$$

$$\frac{di}{dv} = \underbrace{-i_0\left(e^{\frac{v+iR}{V_T}}\right)}\cdot\left(\frac{1}{V_T} + \frac{R}{V_T}\frac{di}{dv}\right)$$

$\cong -i_L$ near open circuit

$$\left.\frac{di}{dv}\right|_{V_{OC}}\left(1 + \frac{Ri_L}{V_T}\right) = -\frac{i_L}{V_T}$$

$$\left.\frac{di}{dv}\right|_{V_{OC}} = \frac{-\frac{i_L}{V_T}}{1 + \frac{Ri_L}{V_T}} = -\frac{1}{\frac{V_T}{i_L} + R}$$

$$\left(\frac{di}{dv}\right)^{-1} = -\frac{V_T}{i_L} - R \Rightarrow R = -\frac{V_T}{i_L} - \left[\left.\frac{di}{dv}\right|_{V_{OC}}\right]^{-1}$$

In this case

$$R = -\frac{0.025}{.020} + \left(\frac{0.010}{0.05}\right)^{-1} = 3.71\ \Omega$$

4. A p-n junction solar cell has $V_{oc} = 0.6$ V and $J_{sc} = 30$ mA/cm^2. A second cell, of the same area, has $V_{oc} = 0.7$ V and $J_{sc} = 12$ mA/cm^2. Assume that both cells obey the ideal diode equation,

   a) Find the values of V_{oc} and J_{sc} when the two are connected in parallel?

   b) Find the values of V_{oc} and J_{sc} when the two are connected in series?

a) In parallel, $J_{sc} = 12 + 30 = 42$ mA/cm^2.

$$J_{01} = \frac{J_{sc1}}{\left(e^{V_{oc,1}/V_T} - 1\right)} = 2.61 \times 10^{-9} \quad \text{and} \quad J_{02} = 2.2 \times 10^{-11}$$

so $J = J_{sc} + (J_{01} + J_{02})\left(e^{V/V_T} - 1\right) = 42 + 2.63 \times 10^{-9}\left(e^{V/V_T} - 1\right)$

$$\Rightarrow V_{oc} = V_T \ln\left(\frac{42}{2.63E-9} + 1\right)$$

$$= 0.61 \text{ V}$$

b) Series

$V_{oc} = 0.6 + 0.7 = 1.3$ V

$J_{sc} = 12$ mA/cm^2 (series limit)