

### 3.15 Electrical, Optical, and Magnetic Materials and Devices

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#### Problem Set #4      Photodevices

Out 18 Oct, due 25 Oct. 2006

1. This question concerns the solar panel which we examined in class.
  - a) Plot the I-V data which we measured on top of the darkened and fully-illuminated curves (a copy is attached to this problem set).
  - b) How many times brighter would the light have to be compared to what we measured for the cell to be 'fully illuminated'? Is it reasonable to expect the panel to achieve full illumination at any time in the year?
  - c) How long would the cell have to operate in Boston in October to obtain 1kWh power (i.e. about 20c worth of electricity)?
  - d) What is the ideal resistance of the load for the cell to generate maximum power under full illumination? Is this consistent with typical loads presented by, for example, an electric light bulb or an electric motor?
  - e) Why were the 36 cells connected in series? What would the optimum resistive load be if they were connected in parallel?
  - f) Each cell passes about 60 mA under about 0.5 V forward bias in the dark. Previously we found that a typical pn junction allows about 1 mA to pass under about 0.5 V forward bias. What is the reason for this difference?
  - g)  $J_0$  for the cell in the dark is  $2.5 \cdot 10^{-12}$  A/cm<sup>2</sup>. Given typical doping levels, what does this imply about the quality of the silicon needed for the cell, as compared to microelectronic-grade silicon?
  
2. a) A photovoltaic cell has a value of  $I_0 = 10^{-6}$  A and  $I_G = -2$ A. Its internal resistance is 0.1 ohm. Estimate the best choice of load resistance in order to get the most power out of the cell, and what the maximum power is. (You do not have to calculate it exactly).  
b) Why is the maximum efficiency of a Si solar cell only about 30%? Give at least 3 reasons.
  
3. Design a silicon *pin* photodiode of area 1 mm<sup>2</sup> with as fast a response time as possible when used in conjunction with a 50  $\Omega$  load resistor. Take  $\epsilon_r = 11.8$  and  $v_s$ , the electron saturation drift velocity, as  $10^5$  m/s. Address the following points:
  - Determine the optimum thickness of each layer
  - Describe an optimum doping arrangement
  - Over what wavelength range would you expect the device to be most effective?
  - Describe the expected frequency response
  - Estimate the minimum detectable input light intensity

There is no one 'right' answer for this. To obtain credit, clearly explain your assumptions and reasoning.

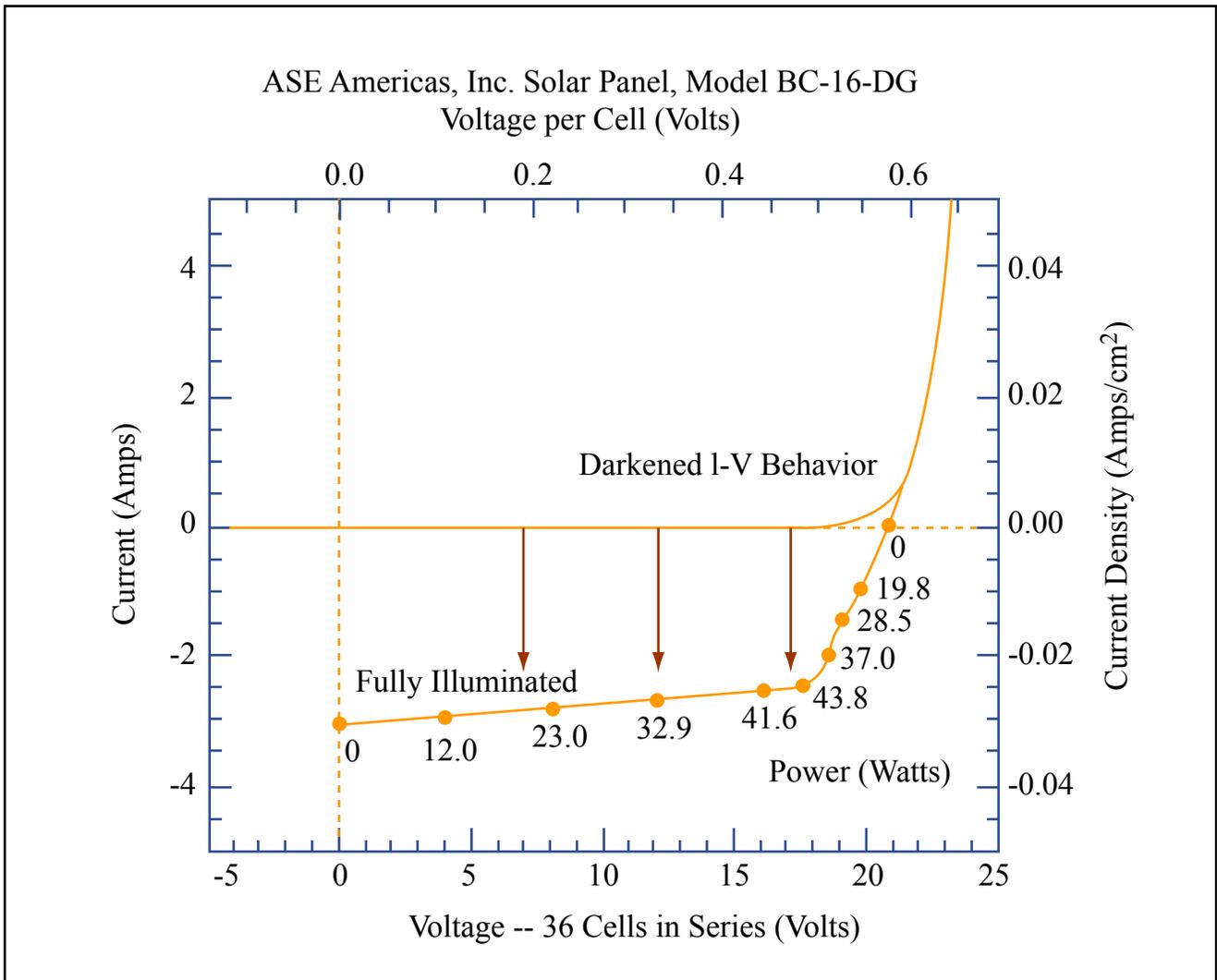


Figure by MIT OCW.