EE 119 Homework 8

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Due Tuesday, April 13th 2010
(Please submit your answers in EE119 homework box located in 240 Cory Hall)

1. **Solar Cell**

Tired of paying outrageous energy bills and afraid of future rolling blackouts, Uncle Mac is determined to become energy self-sufficient. He wants to power his house with solar panels and comes to you for help. You know that a solar cell can be modeled simply as photodiode where the built-in potential of the p-n junction provides the output voltage and the intensity of the sun converted into electrons provides the output current (see figure 1). He finds in a catalog 10cm x 10cm solar cells made of doped crystalline silicon (Bandgap = 1.1eV, estimated output voltage = 0.5V, quantum efficiency = 15%, loss due to heat generated by photons with energy greater than the bandgap = 40%, cost per panel including all electronics = $20.00). Not sure what to do, he comes to you for help.

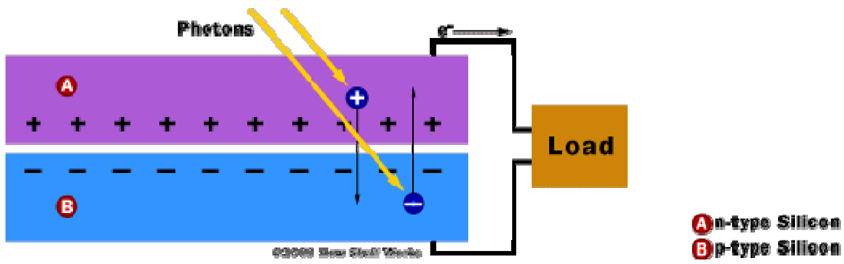

Figure. 1

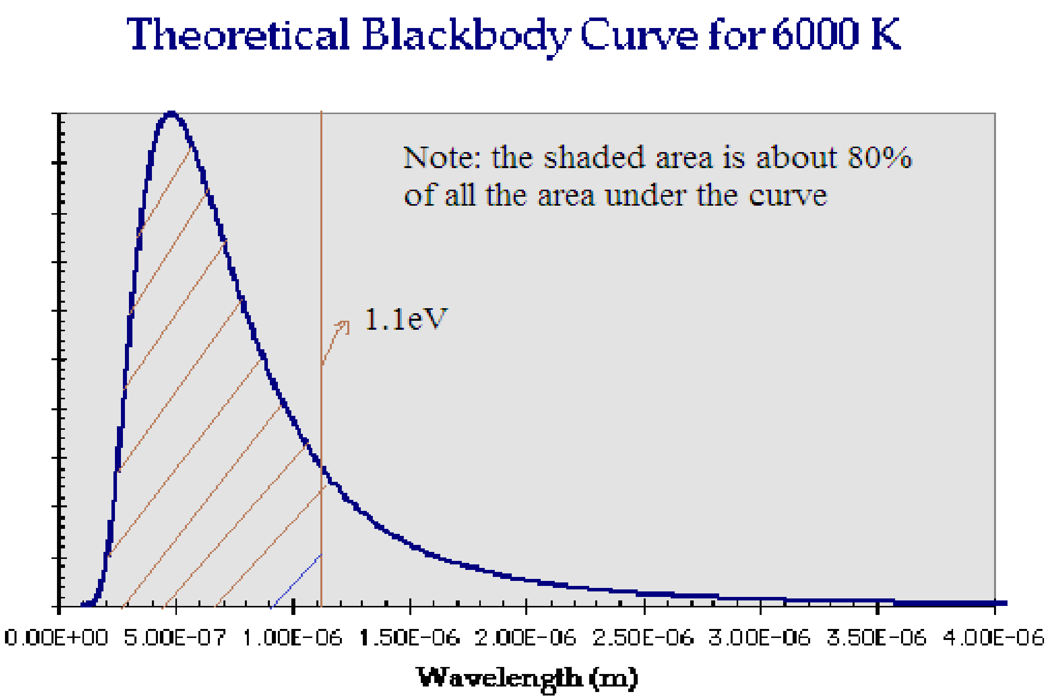

Figure 2

You know that the intensity spectrum of the sun can be modeled as that of 6000K blackbody radiation (see figure 2), normalized to 1000 W/m^2 (average intensity at the earth's surface). Also, knowing that Uncle Mac's house requires on average 550W of power at 120V, help Uncle Mac to design a system of solar cells to power his house. How much is it going to cost? Assume here the absorption of the above-bandgap light in Si is complete.

He also sees in the catalog a solar cell made of GaAs (Bandgap = 1.42eV). Comment on what advantages and disadvantages you might see to use GaAs instead of Si.

2. **Charge-Coupled Devices**. Calculate the pixel data transfer rate in bytes/sec (1 byte per pixel) for a CCD camera, operating at a video frame rate of 30 frames/sec, with a) 256 pixels by 256 pixels, b) 242 pixels by 770 pixels, c) 1024 pixels by 1024 pixels, and d) 4192 pixels by 4192 pixels. Please note

3. **Well depth**: The potential well in a CCD pixel will continue to collect all available electronic charges until it is filled with electrons. When the potential well is completely filled with charges, this is the saturation point of the detector and this is the maximum capacity of the potential well. In this problem, you will calculate this maximum well capacity, also called the well depth.

   We have a CCD camera with 242 pixels (vertical) by 350 pixels (horizontal), operating at a video frame rate of 30 frames/sec, and each pixel is made with a MOS structure. The size of the CCD is 4.8mm (V) by 6.4mm (H). The CCD is saturated when the incident power density is 0.05 $\mu W/cm^2$ at the wavelength of 630nm. The quantum efficiency at that wavelength is 56%. You can ignore the gap between each pixel.
   (a) Calculate the well depth of the CCD (in # of electrons).
   (b) Now, we want to use that CCD to detect radiation from a laser with wavelength of 193nm. The quantum efficiency at that wavelength is 3%. What is the saturation power density for this application?

4. **Picture Contrast Ratio (PCR) and gray scale**. The electro-optic characteristics for a TN-LCD and STN-LCD are given in Figure 3. Two vertical lines in each graph indicate the OFF-ON rms operating voltages for 240:1 multiplexing (this is a dual scan VGA display, so M = 240 instead of 480)
   (a) Which graph corresponds to the characteristics of TN-LCD? Why?
   (b) The Pixel Contrast Ratio (PCR) is defined as follows. Calculate the PCR for a VGA TN-LCD display.

$$PCR = \frac{L_{\text{on}} + (M-1)L_{\text{off}}}{ML_{\text{off}}}$$

   M = number of display rows, L = Transmitted luminance

(c) Calculate the PCR for a STN-LCD display.

(d) What is the maximum allowable change in pixel voltage during a single frame time for a 6 bit gray scale for TN-LCD and STN-LCD? For which display is it easier to control the gray scale?

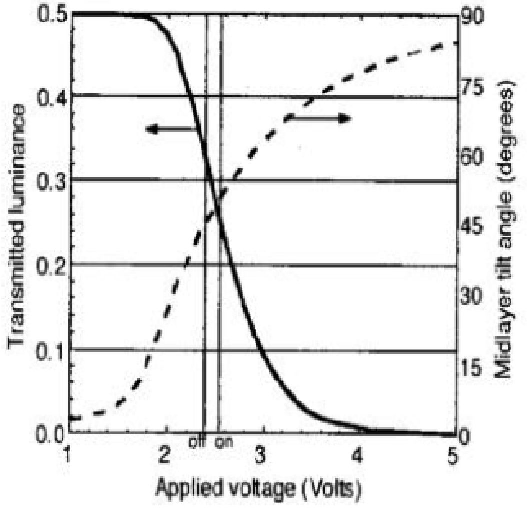

Figure 3 (1)

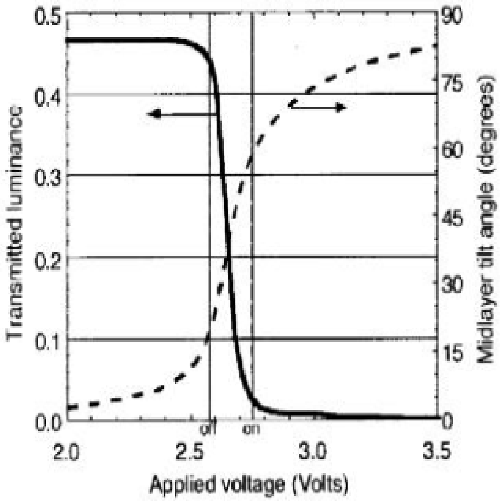

Figure 3(2)

5. **Laser operation**

(a) A particular laser has a cavity of two mirrors with $R_1 = .97$ and $R_2 = .9999$. What must the round-trip gain G be for steady-state laser oscillation? Assume there are no losses in the laser except for the loss from mirrors. Remember that for the steady-state laser oscillation, round-trip gain ($G = e^{2gL}$) must equal to round-trip loss.

(b) The gain medium has a length of 1 micron. For steady-state oscillation, what is the gain coefficient, g, in /cm?