Light Intensity and Probability Worksheet

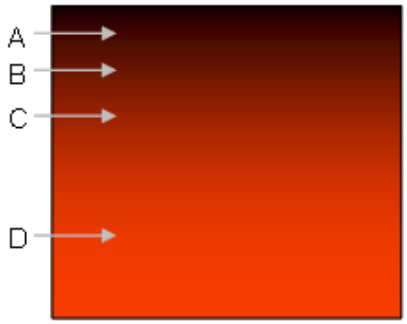
1. A digital camera basically has an array of tiny light detectors (2000x1500 = 3MegaPixels = 3 million very tiny detectors covering a cm^2 or so). In each of these detectors, photons that hit the detector excite electrons and these excited electrons are counted.

   a. In a typical picture, the detector array in the camera is exposed to about 3E-6 Watts of light for 10 ms. If you take 550 nm as an average wavelength for the light, what is the average number of photons that hit each pixel in a typical picture?

   b. If you have very low intensity green light (4E-11 Watts at 550 nm) evenly illuminating the entire array of detectors, what will the camera's detectors see during the exposure time of 10ms?
      A. All pixels in the array count about the same number of excited electrons
      B. The pixels in the center of the array will count the largest number of excited electrons and this will drop off towards the edges
      C. Random pixels will have several excited electrons, others will have only one excited electron, and others will have no excited electrons.

   c. You now have higher intensity green light (6E-6 Watts at 550 nm) evenly illuminating the entire array of detectors. What will the camera's detectors see during the exposure time of 10ms?
      A. All pixels in the array count about the same number of excited electrons
      B. The pixels in the center of the array will count the largest number of excited electrons and this will drop off towards the edges
      C. Random pixels will have several excited electrons, others will have only one excited electron, and others will have no excited electrons.

2. Red laser light and a variable filter are used to create the image below on the detector of a digital camera. For the marked places:



   a. What can you say about the probability that the next photon detected will be found at location A, B, C, or D:
      A. The next photon is equally probably to be found at each of these locations.
      B. The probability that the next photon will be found at A is higher than at B, which is higher than at C, which is higher than at D.
      C. The probability that the next photon will be found at D is higher than at C, which is higher than at B, which is higher than at A.
      D. We cannot say anything about the probability of where the next photon will be detected.

Modified slightly from material developed by Carl Wieman and Sam McKagan of the Physics Education Technology group at the University of Colorado, Boulder.

b. Rank the absolute value of the magnitude of the electromagnetic wave at these points:

A. Magnitude of the electromagnetic wave at A = B = C = D

B. Magnitude of the electromagnetic wave at D > C > B > A

C. We cannot say anything about the magnitude of the electromagnetic wave at these points

c. Increasing the intensity of the laser, means (check all that apply):

- ☐ increasing the energy of each photon
- ☐ decreasing the energy of each photon
- ☐ increasing the number of photons
- ☐ decreasing the number of photons
- ☐ increasing the amplitude of the electromagnetic wave
- ☐ decreasing the amplitude of the electromagnetic wave
- ☐ increasing the total energy in the laser beam
- ☐ decreasing the total energy in the laser beam
- ☐ increasing the wavelength of the light
- ☐ decreasing the wavelength of the light