UNIVERSITY OF CALIFORNIA
College of Engineering
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EE290D — Handout #21
Spring 1999 — T.-J. King

HOMEWORK ASSIGNMENT #2 SOLUTIONS

Problem 1:

CORRECTION: The brightness of a perfectly diffusing (Lambertian) surface is given by the equation

$$\mathbf{B = I \cos\theta / \pi S^2}$$

(Note that 1 cd/ft^2 = π fL = 3.142 fL.)

a) I = 10 cd; $\theta = 0^o$; S = 10 ft => **B = 0.1/π cd/ft^2 = 0.1 fL**

b) I = 10 cd; $\theta = 45^o$; S = 1 ft => **B = 7.07/π cd/ft^2 = 7.07 fL**

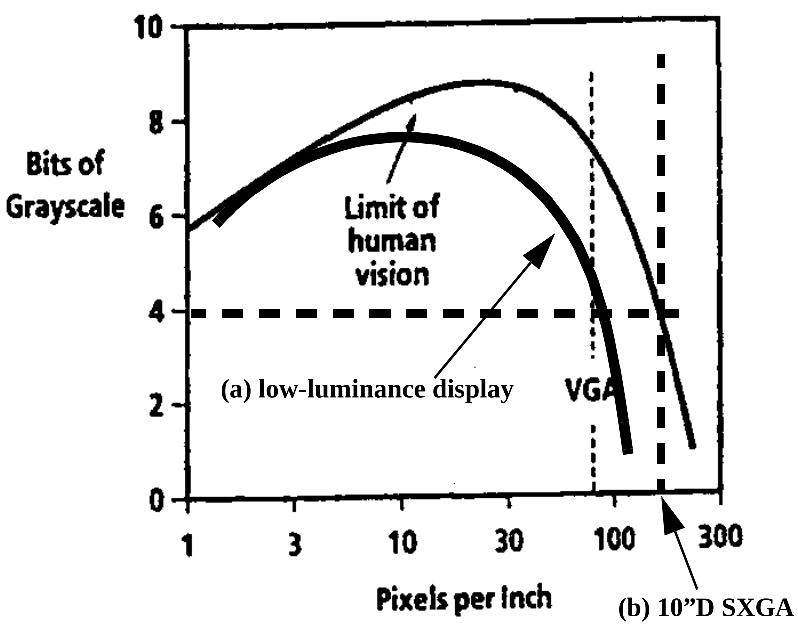
Problem 2:

a) The cone photoreceptors in the retina have greater resolving power than the rod photoreceptors, but they are much less sensitive to light than the rod photoreceptors. At low illuminations, only the rods are sensitive to light and hence visual acuity decreases.

b) The ambient level of illumination is very low in a movie theatre environment, and the screen is of commensurately low luminance. Since the sensitivity of the eye to flicker decreases (*i.e.* the integration time increases) with decreasing retinal illuminance, images viewed in a movie theatre do not need to be refreshed as rapidly as images viewed on a television screen. (Ambient room lighting is generally at much higher levels than in a movie theatre, and hence a television set is usually operated at correspondingly high brightness levels.)

Problem 3:

a) From the Contrast Threshold Function curves (Page 7 of Lecture #4 Notes), we find that as the display luminance decreases, the CTF minimum increases and shifts to lower frequencies. **The Contrast Sensitivity Function peak will hence decrease and shift to lower frequencies:**



b) For a 10"D SXGA display (1280 x 1024 pixels -- note that the aspect ratio is 5:4, not 4:3!), the number of pixels per inch = $1280/[(10)(5)/(4^2+5^2)^{0.5}] = 164$ dpi. From the plot above, we can see that only **4 bits of grayscale** are detectable.

Problem 4:

The luminous flux of a light source is given by the equation:

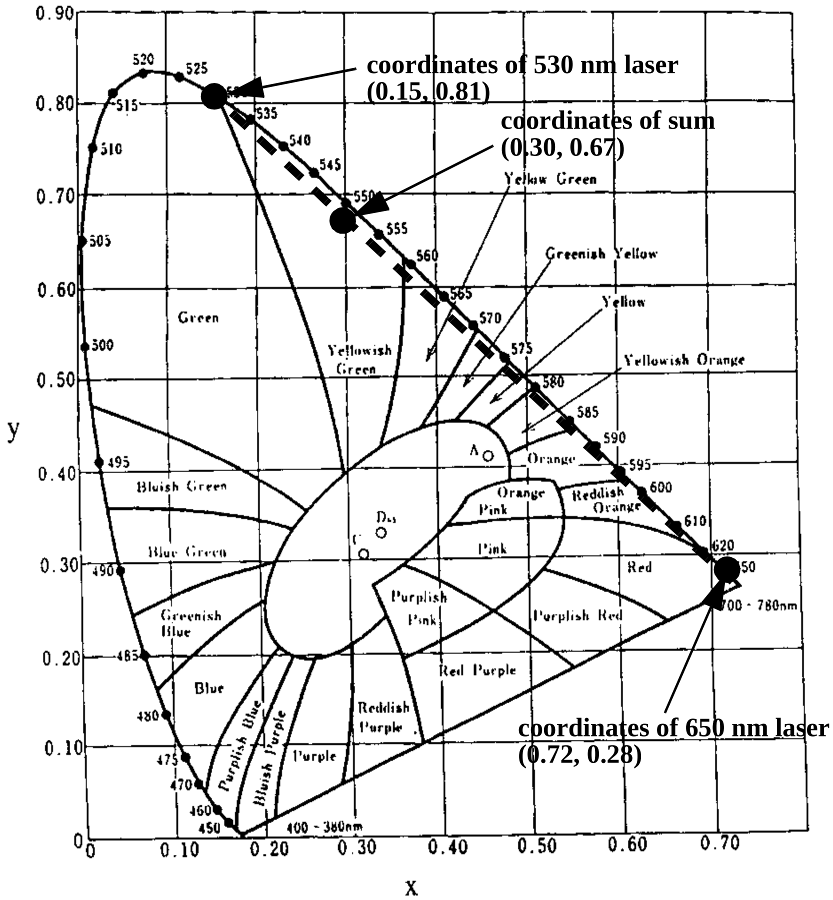
$$L = 683 \int_{380nm}^{780nm} P(\lambda)V(\lambda)d\lambda$$

where $P(\lambda)$ is the spectral radiance of the light source and $V(\lambda)$ is the visual response function. (The visual response function is the same as the $\bar{y}$ basis function given in the Lecture #6 Notes.)

a) For a 5 mW 530 nm laser: $P(\lambda) = 0.005\ \delta(530\text{ nm})$ W/µm where $\delta(530\text{ nm})$ is the impulse function.
L = 683 x 0.005 x V(530 nm) = 683 x 0.005 x 0.86 = **2.94 lumens**

b) For a 5 mW 650 nm laser: $P(\lambda) = 0.005\ \delta(650\text{ nm})$ W/µm.
L = 683 x 0.005 x V(650 nm) = 683 x 0.005 x 0.11 = **0.38 lumens**

c) Lasers are monochromatic and hence are “100% pure”; their coordinates should be located on the spectrum locus as shown below:



d) The X, Y, Z tristimulus coordinates for a light source with spectral radiance *P(λ)* are given by the following equations;

$$X = 683 \int_{380nm}^{780nm} P(\lambda)\bar{x}(\lambda)d\lambda$$

$$Y = L = 683 \int_{380nm}^{780nm} P(\lambda)\bar{y}(\lambda)d\lambda$$

$$Z = 683 \int_{380nm}^{780nm} P(\lambda)\bar{z}(\lambda)d\lambda$$

(The $\bar{x}$ and $\bar{z}$ basis functions are given in the Lecture #6 Notes.)

To find the coordinates of the two colors:

i) $\bar{x}$ (530 nm) = 0.16; $\bar{y}$ (530 nm) = 0.86; $\bar{z}$ (530 nm) = 0.04

X_{530nm} = 683 x 0.005 x 0.16 = 0.55
Y_{530nm} = 2.94 (from part a)
Z_{530nm} = 683 x 0.005 x 0.04 = 0.14
$T_{530nm} = X_{530nm} + Y_{530nm} + Z_{530nm}$ = 3.63
normalized coordinates:
$x_{530nm} = X_{530nm}/T_{530nm}$ = 0.15
$y_{530nm} = Y_{530nm}/T_{530nm}$ = 0.81
$z_{530nm} = Z_{530nm}/T_{530nm}$ = 0.04

ii) $\bar{x}$ (650 nm) = 0.28; $\bar{y}$ (650 nm) = 0.11; $\bar{z}$ (650 nm) = 0.00

X_{650nm} = 683 x 0.005 x 0.28 = 0.96
Y_{650nm} = 0.38 (from part b)
Z_{650nm} = 683 x 0.005 x 0.00 = 0.00
$T_{650nm} = X_{650nm} + Y_{650nm} + Z_{650nm}$ = 1.34
normalized coordinates:
$x_{650nm} = X_{650nm}/T_{650nm}$ = 0.72
$y_{650nm} = Y_{650nm}/T_{650nm}$ = 0.28
$z_{650nm} = Z_{650nm}/T_{650nm}$ = 0.00

To find the coordinates of the sum of the two colors:

$$x_{sum} = \frac{x_{530nm}T_{530nm} + x_{650nm}T_{650nm}}{T_{530nm}T_{650nm}} = \mathbf{0.30}$$

$$y_{sum} = \frac{y_{530nm}T_{530nm} + y_{650nm}T_{650nm}}{T_{530nm}T_{650nm}} = \mathbf{0.67}$$

This is plotted on the CIE chart above.

<u>Problem 5</u>:

a) For PDA devices, low cost and low power are of primary importance for the display. STN-LCD technology leads all other FPD technologies in these two respects.

b) For laptop computer applications, the display must have good picture quality (high resolution, color, gray scale, high contrast ratio) in addition to acceptable cost. AMLCD technology is presently the only technology which meets these requirements.