Computer Graphics	**Doug Johnson**
CSE 457	**Autumn 2003**

Homework #1

Visual Perception, Color, Image Processing, Affine Transformations

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Assigned: Friday, October 17th
Due: Friday, October 31st

Directions: Please provide short written answers to the questions in the space provided. If you require extra space, you may staple additional pages to the back of your assignment. Feel free to talk over the problems with classmates, but please *answer the questions on your own*.

Name:____

Problem 1. Short answer (12 points, 2 each)

Provide a short answer (typically one or two sentences) to each of the following questions. In each case, you must clearly justify your answer.

a. Describe the distribution of rods and cones in your eye. How is this related to acuity and sensitivity?

b. How can the second derivative be used in edge detection to improve the results?

c. Why do we use a 4x4 matrix for transformations in 3-space?

d. At 24 bits per pixel (True Color), can a monitor produce every color perceptible to the human eye?

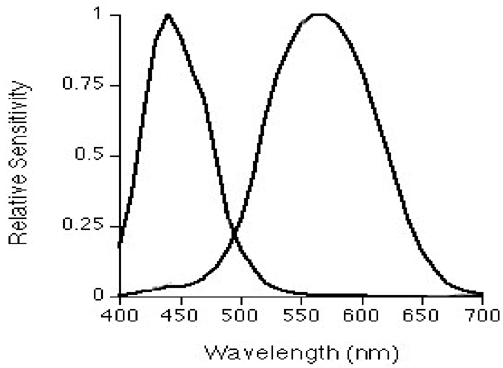
e. Describe how identical electrons on the cathode of a CRT tube can produce different color sensations in the brain. Briefly describe each step from cathode to optic nerve.

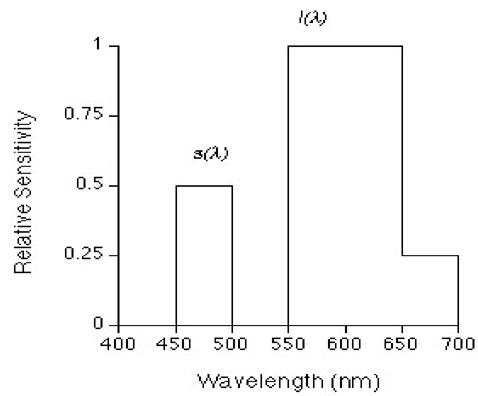
f. Suppose we wish to display five colors of equally spaced intensity levels with initial intensity 1/81 and final intensity 1. What should the intermediate intensities be?

Problem 2. Color perception (19 points)

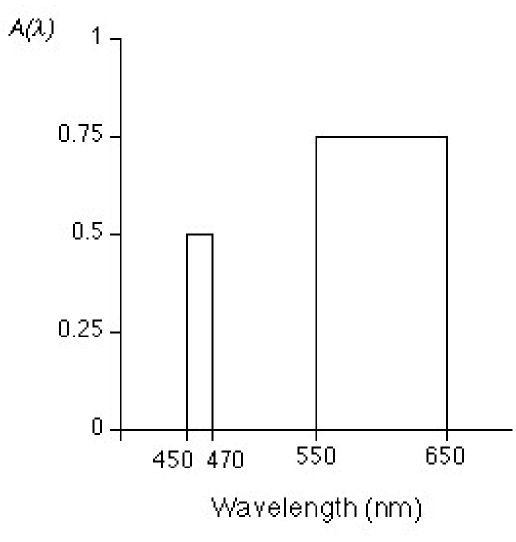
Dichromatic color blindness occurs in people who are missing one of the three types of retinal cones. People with dichromatic vision are true color blinds in the sense that there are hues that they cannot perceive. Two light sources which are perceived to be different by people with normal vision will be metamers to those with dichromatic vision if they create the same activation ratio in their remaining two cone classes.

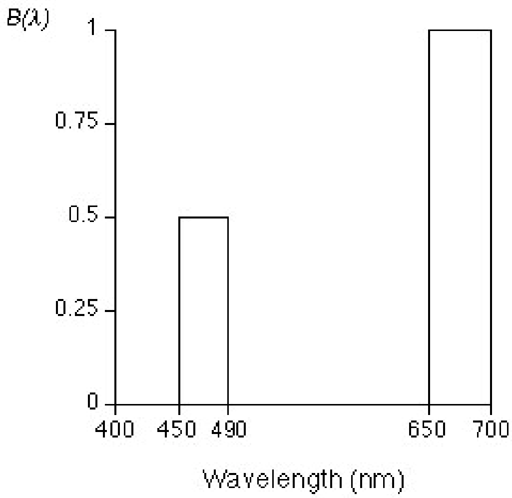
The most common type of dichromatic vision in humans occurs in people missing M-cones (deuteranope). The result is one type of red-green colorblindness. The graph on the left is the spectral sensitivity graph for this kind of colorblindness. The graph on the right is an approximation of the spectral sensitivity graph for this type of colorblindness. (Note that both functions are drawn on each graph: S-cone sensitivity on the left and L-cone sensitivity on the right.)



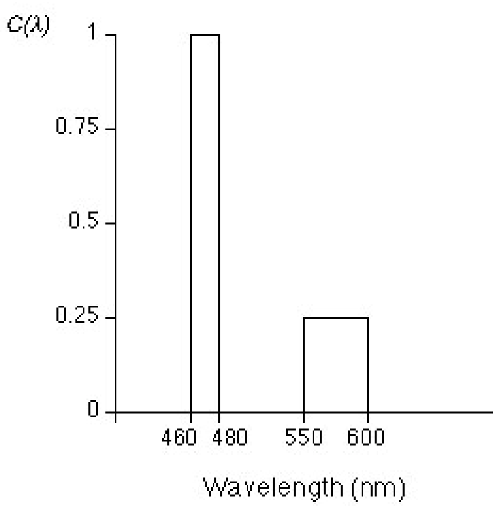


(a) (9 points) Determine which, if any, of the following lights would be perceived as metamers by a person with dichromatic vision. Show your work in the column next to the spectral plots.





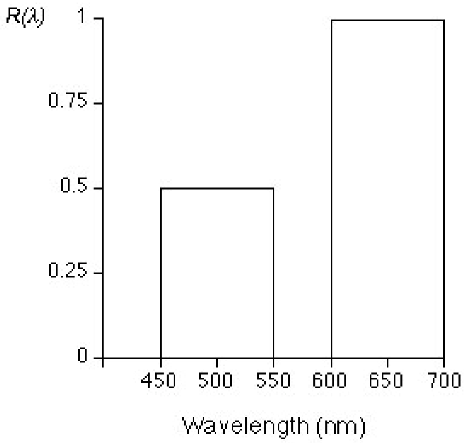
B(λ)
1
0.75
0.5
0.25
0
400
450
490
650
700
Wavelength (nm)



C(λ)
1
0.75
0.5
0.25
0
460
480
550
600
Wavelength (nm)

Problem 2 (cont.)

(b) (10 points) All three lights from the previous part shine on different parts of a surface whose reflectance is graphed below. Determine under which of the lights, if any, the surface will yield subtractive metamers for people with dichromatic color blindness. (You need only consider the reflection of one light at a time. Do not worry about contributions from multiple lights.)



Problem 3. Image Filters (15 points)

a. Adobe Photoshop is a good place to look for Image Processing ideas. Explore some of Photoshop's filters. Pick one of the "interesting" filters not covered in lecture and describe its effects as best you can by reading the help information and experimenting with the filter. Then describe how you might implement a similar filter capability in Impressionist. Note that these Photoshop filters are not just convolution kernels, they do anything they need to in order to create an effect. Several steps might be involved. It's okay if you can't describe the effect of every parameter; you don't have the source code and neither do we. (5 points)

b. Describe the effects of each of the following filters. Also, which filter will cause the most blurring and which will produce the brightest image? Justify your answers. (10 pts)

0	-1	0
-1	5	-1
0	-1	0

0	0	0
0	1	0
0	0	0

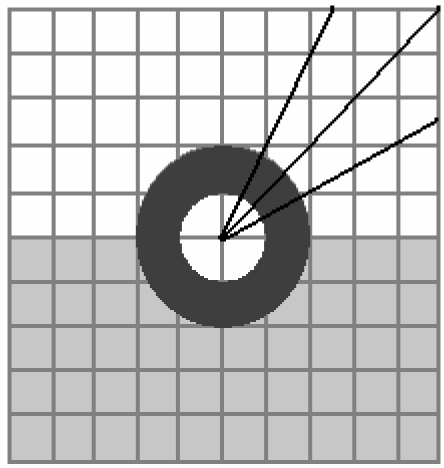
0	0	0
.3	.3	.3
0	0	0

0	.15	0
.15	.5	.15
0	.15	0

.1	.1	.1
.1	.1	.1
.1	.1	.1

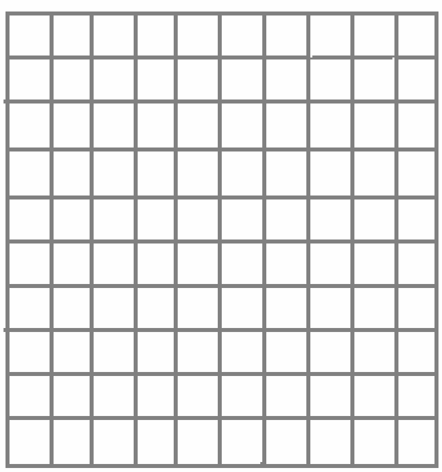
Problem 4. Image Processing (18 points)

Below are some Image Processing functions of the form $g(x, y) = f(x', y') = f(u(x,y), v(x,y))$ in Cartesian coordinates or $g(r, \theta) = f(r', \theta') = f(u(r, \theta), v(r, \theta))$ in polar coordinates. Sketch the result of each transformation when applied to the image below. You may find it helpful to consider $x' = u(x, y)$ to be an inverse mapping function and find the related forward mapping function $x = u'(x', y')$.

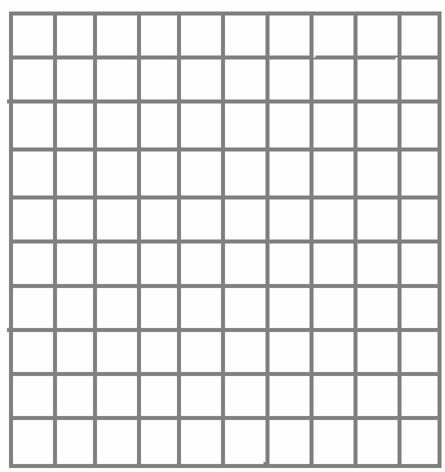


Original Image: f

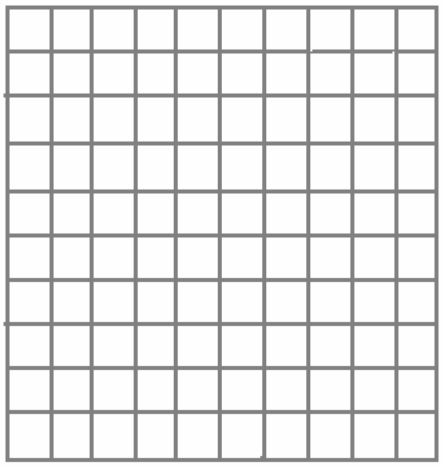
a. $g(x,y) = f(x, -2y)$



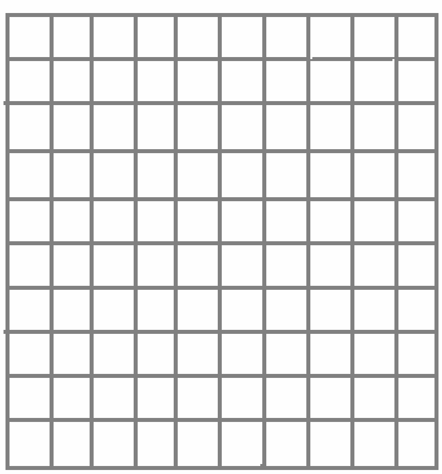
b. $g(x,y) = f(x, y/-2)$



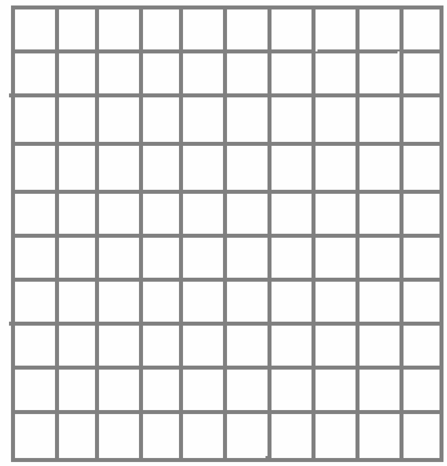
c. $g(x,y) = f(x, -y^2)$



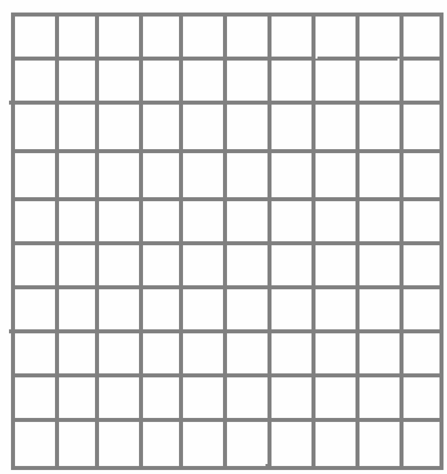
d. $g(r,\theta) = f(\sqrt{r}, -\theta)$



e. $g(r, \theta) = f(r, \theta + r)$



f. $g(r, \theta) = f(\theta, r)$



Problem 5. Affine Transformations (25 points)

$$A=\begin{bmatrix}0 & 0 & -1 & 0\\ 0 & 1 & 0 & 1\\ 1 & 0 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\quad B=\begin{bmatrix}1 & 0 & 0 & 1\\ 0 & 1 & 0 & 1\\ 0 & 0 & 1 & 2\\ 0 & 0 & 0 & 1\end{bmatrix}\quad C=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 0 & -1 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$D=\begin{bmatrix}1 & 0 & -1 & 0\\ 0 & 1 & 0 & 0\\ 1 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\quad E=\begin{bmatrix}3 & 0 & 0 & 0\\ 0 & 3 & 0 & 0\\ 0 & 0 & 3 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\quad F=\begin{bmatrix}-1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$G=\begin{bmatrix}1 & 0 & 0 & 0\\ 1 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\quad H=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 3 & 0 & 0\\ 0 & 0 & 2 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\quad I=\begin{bmatrix}0 & 1 & 0 & 0\\ -1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

(a) (2 points per matrix) As discussed in class, any three-dimensional affine transformation can be represented with a 4x4 matrix. Match the matrices above to the following transformations (not all blanks will be filled):

____ Rotation about the x-axis

____ Rotation about the y-axis

____ Rotation about the z-axis

____ Rotation about the y-axis with non-uniform scaling

____ Rotation about the z-axis with non-uniform scaling

____ Rotation about the y-axis and translation

____ Differential (Non-Uniform) Scaling

____ Uniform Scaling

____ Reflection with uniform scaling

____ Reflection

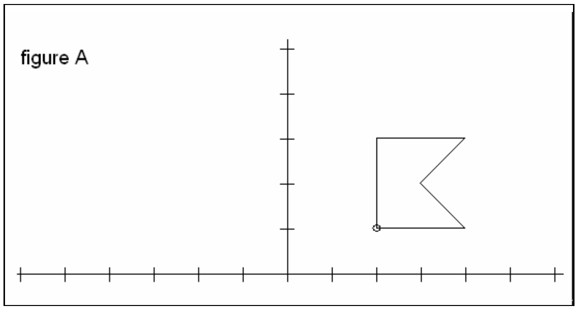
____ Translation

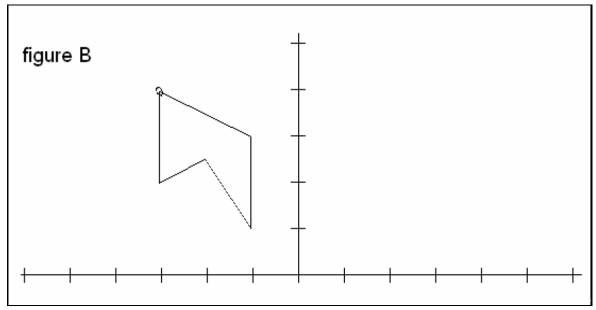
____ Shearing with respect to the x-y plane

____ Shearing with respect to the y-z plane

Problem 5 (cont.)

(b) (7 points) **Figure B** shows the result of applying an affine transformation to the geometry in **figure A**. Determine a product of 3x3 matrices that perform this transformation. Do not multiply the matrices out. There is more than one way to arrive at an answer, so please explain your reasoning.





Extra Credit (10 points)

Using the Euler angle rotation matrices Rx(α),Ry(α) and Rz(α) (parameterized by the angle α) as building blocks, specify how one could build a transformation matrix which rotates around the arbitrary axis vector **v**=(x,y,z) by the angle θ. In words and drawings, describe all parts of the construction. You don't need to compute exact formulas for the rotation angles, but you must describe how to compute each of the rotation angles.