1. **Color:** (5 points)
   
   (a) “tristimulus values” is the correct answer for both parentheses
   
   (b) u-v
   
   (c) tristimulus values
   
   (d) both pure red and reference white, trichromatic coefficients
   
   Grading: 1 point each for parts a,b,c, and 2 points for part d

2. **Distance transformations (7 points):**
   
   (a) The distance between the origin and an arbitrary point \((x,y)\) according to City-Block distance is \(d_{City} = |x| + |y|\), and according to Chessboard distance is \(d_{Chess} = \max\{|x|, |y|\}\)
   
   (b) The Euclidean Distance is \(EDT(A, B) = \sqrt{x^2 + y^2}\).

   Chessboard distance counts a step horizontally or vertically as being the same unit distance as a step diagonally (the way a king moves). (See grid below left.) So ChessboardDT(A,B) = 2.

   The city block distance never allows you to take a step diagonally; you must only move unit distances along city streets. So CityBlockDT(A,B) = 3. (See grid below middle).

   The Chamfer3-4 DT counts a horizontal (or vertical) step as 3 units, and a diagonal one as 4 units. After you have added up the total distance, you normalize by dividing the total by 3. (See grid below right). So Chamfer3-4DT(A,B) = \(\frac{7}{3}\).

   \[
   \begin{array}{ccccc}
   2 & 2 & 2 & 2 & 2 \\
   2 & 1 & 1 & 1 & 2 \\
   2 & 1 & 0 & 1 & 2 \\
   2 & 1 & 1 & 1 & 2 \\
   2 & 2 & 2 & 2 & 2 \\
   \end{array} \quad \begin{array}{ccccc}
   4 & 3 & 2 & 3 & 4 \\
   3 & 2 & 1 & 2 & 3 \\
   2 & 1 & 0 & 1 & 2 \\
   3 & 2 & 1 & 2 & 3 \\
   4 & 3 & 2 & 3 & 4 \\
   \end{array} \quad \begin{array}{ccccc}
   8 & 7 & 6 & 7 & 8 \\
   7 & 4 & 3 & 4 & 7 \\
   6 & 3 & 0 & 3 & 6 \\
   7 & 4 & 3 & 4 & 7 \\
   8 & 7 & 6 & 7 & 8 \\
   \end{array} \quad \frac{1}{3} \times
   
   \]

   (c) We are trying to show that City-Block distance is always equal to or greater than Euclidean distance:
   
   \[|x| + |y| \geq \sqrt{x^2 + y^2}\]
   
   both sides are non-negative and we can square both sides to get
   
   \[x^2 + y^2 + 2|x||y| \geq x^2 + y^2\]
   
   which is true.

   Grading: 1 point for each distance formula in part (a), 0.5 points for each distance in part (b), 3 points for part (c).
3. **Binary Image Processing: Pruning (7 points)**

   Grading: (a) 5 points (0.5 for each marked pixel), (b) 2 points.

4. **Amplitude Thresholding: (4 points)**

   Internal angles are less than or equal to 180 degrees. Grading: 2 points each part.

5. **K-means Clustering: (6 points)**

   The dividing line is perpendicular to the line which connects the 2 cluster centers, and is halfway between:
The new cluster centers are the centroids of the points on the two sides of the line:

![Cluster Centers Diagram]

Grading: 1.5 points for each.

6. **More Color: (6 points)**

The RGB color planes are in the order: B, R, G. It is fairly clear that the middle one is Red because that is the brightest overall, and the picture has a lot of red and orange. The green stems are brighter in the righthand picture than in the lefthand one, which helps determine that the righthand picture is G.

The HSI color planes are in the order: H, I, S. The easiest one to tell is the H plane, because that one shows false contours. That is, since pure red is the reference for hue, there are reds which are at zero or just above zero, and reds which are very similar in hue which have values at 1 or just below 1. So there are some sharp black/white transitions in the image. The middle picture is the I plane since that one looks most like a reasonable grayscale version.