2.1 Using the background information provided in Section 2.1, and thinking purely in geometric terms, estimate the diameter of the smallest printed dot that the eye can discern if the page on which the dot is printed is 0.3 m away from the eyes. Assume for simplicity that the visual system ceases to detect the dot when the image of the dot on the fovea becomes smaller than the diameter of one receptor (cone) in that area of the retina. Assume further that the fovea can be modeled as a circular array of diameter 1.5 mm and that the cones and spaces between the cones are distributed uniformly throughout this array.

2.5 A CCD camera chip of dimensions 14×14 mm, and having 2048×2048 elements, is focused on a square, flat area, located 0.5 m away. How many line pairs per mm will this camera be able to resolve? The camera is equipped with a 35-mm lens. (*Hint:* Model the imaging process as in Fig. 2.3, with the focal length of the camera lens substituting for the focal length of the eye.)

★2.6 An automobile manufacturer is automating the placement of certain components on the bumpers of a limited-edition line of sports cars. The components are color coordinated, so the robots need to know the color of each car in order to select the appropriate bumper component. Models come in only four colors: blue, green, red, and white. You are hired to propose a solution based on imaging. How would you solve the problem of automatically determining the color of each car, keeping in mind that *cost* is the most important consideration in your choice of components?

2.7 Suppose that a flat area with center at (x_0, y_0) is illuminated by a light source with intensity distribution

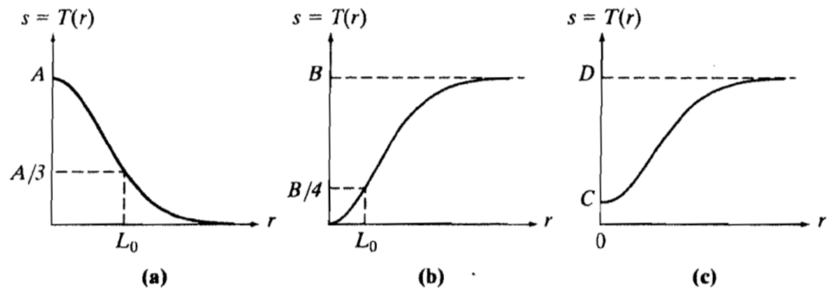
$$i(x, y) = Ke^{-[(x-x_0)^2+(y-y_0)^2]}$$

Assume for simplicity that the reflectance of the area is constant and equal to 1.0, and let $K = 255$. If the resulting image is digitized with k bits of intensity resolution, and the eye can detect an abrupt change of four shades of intensity between adjacent pixels, what value of k will cause visible false contouring?

★2.11 Consider the two image subsets, S_1 and S_2, shown in the following figure. For $V = \{1\}$, determine whether these two subsets are (a) 4-adjacent, (b) 8-adjacent, or (c) m-adjacent.

	S_1				S_2				
0	0	0	0	0	0	0	1	1	0
1	0	0	1	0	0	1	0	0	1
1	0	0	1	0	1	1	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	1	1	1

3.2 Exponentials of the form $e^{-\alpha r^2}$, with α a positive constant, are useful for constructing smooth intensity transformation functions. Start with this basic function and construct transformation functions having the general shapes shown in the following figures. The constants shown are *input* parameters, and your proposed transformations must include them in their specification. (For simplicity in your answers, L_0 is not a required parameter in the third curve.)



3.3 ★**(a)** Give a continuous function for implementing the contrast stretching transformation shown in Fig. 3.2(a). In addition to m, your function must include a parameter, E, for controlling the slope of the function as it transitions from low to high intensity values. Your function should be normalized so that its minimum and maximum values are 0 and 1, respectively.

(b) Sketch a family of transformations as a function of parameter E, for a fixed value $m = L/4$, where L is the number of intensity levels in the image.

(c) What is the smallest value of E that will make your function *effectively* perform as the function in Fig. 3.2(b)? In other words, your function does not have to be identical to Fig. 3.2(b). It just has to yield the same result of producing a binary image. Assume that you are working with 8-bit images, and let $m = 128$. Let C denote the smallest positive number representable in the computer you are using.

3.4 Propose a set of intensity-slicing transformations capable of producing all the individual bit planes of an 4-bit monochrome image. (For example, a transformation function with the property $T(r) = 0$ for r in the range [0, 7], and $T(r) = 15$ for r in the range [8, 15] produces an image of the 4th bit plane in an 8-bit image.)

3.5 ★**(a)** What effect would setting to zero the half of lower-order bit planes have on the histogram of an image in general?

(b) What would be the effect on the histogram if we set to zero the half of higher-order bit planes instead?

3.6 Explain why the discrete histogram equalization technique does not, in general, yield a flat histogram.

★**3.9** Assuming continuous values, show by example that it is possible to have a case in which the transformation function given in Eq. (3.3-4) satisfies conditions (a) and (b) in Section 3.3.1, but its inverse may fail to be single valued.