Mechanical Engineering

Computer Graphics and Image Processing

1. Describe the A-buffer polygon scan conversion algorithm using 4 x 4 sub-pixels in each pixel. [10 marks]
2. It is possible to represent continuous tone greyscale images using just black ink on white paper because of limitations in the human visual system. Explain how and why. [4 marks]
3. Describe an algorithm which, given a greyscale image, will produce a black and white (bi-level) image of four times the resolution in each dimension which provides a good approximation to the greyscale image. [6 marks]
4. Give an outline description of the painter's algorithm, z -bu_er and BSP tree methods for rendering a set of 3D polygons. [3 x 4 marks]
5. Compare and contrast the three methods. [8 marks]
6. We use homogeneous coordinates to represent transformations in 3D space:

$$\begin{bmatrix} x'_H \\ y'_H \\ z'_H \\ w'_H \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & b_1 \\ a_{21} & a_{22} & a_{23} & b_2 \\ a_{31} & a_{32} & a_{33} & b_3 \\ c_1 & c_2 & c_3 & d \end{bmatrix} \begin{bmatrix} x_H \\ y_H \\ z_H \\ w_H \end{bmatrix}$$

   i. Explain how to convert standard 3D coordinates, (x,y,z), to homogeneous coordinates and how to convert homogeneous coordinates to standard 3D coordinates. [2 marks]

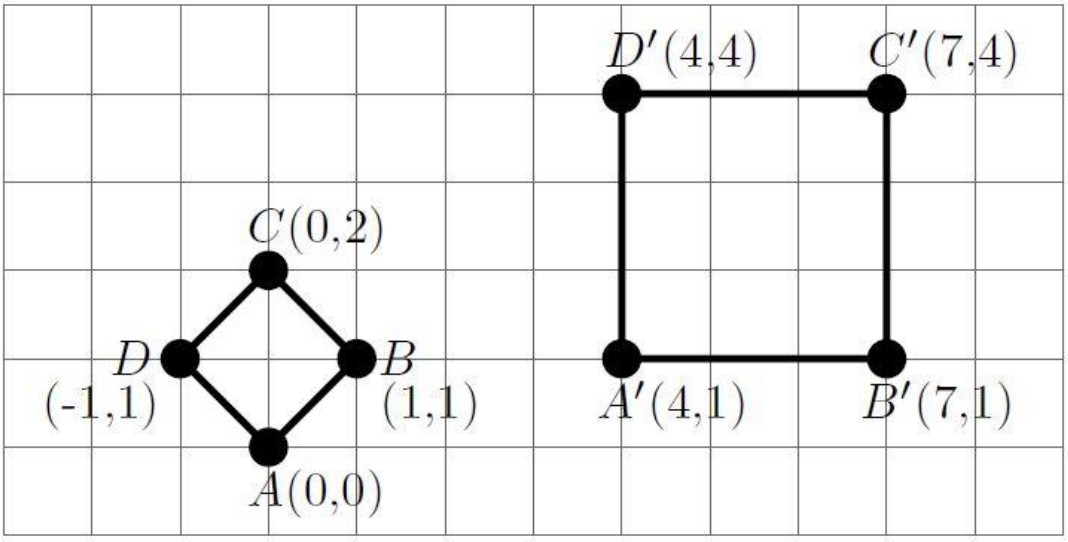
   ii. Describe the types of transformations provided by each of the four blocks of coefficients in the matrix (a11 …. a33, b1 … b3, c1 … c3, and). [6 marks]

   iii. Explain what transformation is produced by each of the following matrices:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & p & -p(1+r) \\ 0 & 1 & q & -q(1+r) \\ 0 & 0 & 1+r & -r(1+r) \\ 0 & 0 & 1 & -r \end{bmatrix}$$

[4 marks]

7. Describe an algorithm (in 2D) which clips an arbitrary polygon against an arbitrary axis-aligned rectangle. [8 marks]
8. Describe an algorithm for performing scan conversion of a set of 3D polygons, including details of clipping, projection, and the underlying 2D polygon scan conversion algorithm. You may assume that you are given the color of each polygon and that no lighting calculations are required. Please state any additional assumptions that you need to make. Ray tracing is not an acceptable answer to this question. [20 marks]
9. We wish to produce two algorithms: one which draws the outline of a circle and one which draws a filled circle.
    i. Describe an efficient algorithm which will draw a one-pixel wide outline of a circle of integer radius, R, centered on the origin. [10 marks]
    ii. Describe the modifications required to your algorithm to make it draw a filled circle. [3 marks]
10. Given a function draw line (x1, y1, x2, y2), describe an algorithm for drawing a Bezier cubic curve to a specified level of accuracy using only straight lines. [7 marks]
11. Explain why display devices appear to be able to reproduce (almost) all the colors of the spectrum using only red, green and blue light. [4 marks]
12. Describe an algorithm (other than thresholding) which will convert a greyscale image (8 bits per pixel) to a bi-level black and white image (1 bit per pixel), with the same number of pixels, while retaining as much detail as possible. [8 marks]
13. Explain what specular and diffuse reflection are in the real world. State and explain equations for calculating approximations to both in a computer. [8 marks]
14. Calculate the maximum resolution needed by a movie projector in a movie theatre. Clearly state any assumptions that you make. [6 marks]
15. Describe, in detail, an error diffusion algorithm for converting greyscale images to bi-level black and white images at the same resolution. [8 marks]
16. Explain how this could be extended to provide an algorithm to print full color RGB images on a CMYK laser printer, assuming that one pixel in the image maps to one pixel on the printer. [6 marks]
17. Describe, in detail, an algorithm to clip a straight line against an axis-aligned rectangle. [10 marks]
18. Explain why homogeneous coordinates are used for handling geometric transformations. [3 marks]



19. Give a matrix, or a product of matrices, which will transform the square ABCD to the square A'B'C'D'. [4 marks]
20. Show what happens if the same transformation is applied to the square A'B'C'D'. [3 marks]
21. In ray tracing, once we have determined where a ray strikes an object, the illumination at the intersection point can be calculated using the formula:

$$I = I_a k_a + \sum_i I_i k_d (\mathbf{L}_i \cdot \mathbf{N}) + \sum_i I_i k_s (\mathbf{R}_i \cdot \mathbf{V})^n.$$

Explain what real effect each of the three terms is trying to model, how accurately it models the real effect, and explain what each of the following symbols means, within the context of this formula:

$$I,\ I_a,\ i,\ I_i,\ k_a,\ k_d,\ k_s, \mathbf{L}_i,\ \mathbf{N},\ \mathbf{R}_i,\ \mathbf{V},\ n.$$

[12 marks]

22. Compare and contrast the ray tracing and z-buffer algorithms. [8 marks]
23. Describe, in outline, each of the z-buffer, BSP tree, and painter's algorithm methods for rendering a set of 3D polygons. [4 marks each]
24. Compare and contrast the three methods. [8 marks]
25. Give the definition of the cubic Bezier curve. [4 marks]
26. Derive the conditions necessary to ensure that two cubic Bezier curves join with C 1-continuity. [6 marks]
27. Describe, in detail, an algorithm for drawing a cubic Bezier curve to a given tolerance using straight lines. You may assume that you already have an algorithm for

drawing a straight line. [6 marks]

28. Explain why and how homogeneous co-ordinates are used in computer graphics. [4 marks]
29. Standard color printing uses the four ink colors: cyan, magenta, yellow and black.
    i. Explain why this is so. [3 marks]
    ii. What benefits are there in using more than these four ink colors? [3 marks]
30. Describe an algorithm for converting a greyscale image to a bilevel (black and white) image while retaining as good a quality as possible. Your algorithm should be for the situation where each greyscale pixel maps to a single bilevel pixel. [6 marks]
31. Describe operations on images which achieve the following effects:
    i. lighten an image which is too dark; [2 marks]
    ii. remove salt and pepper noise ("shot noise") from an image; [2 marks]
    iii. locate 45° edges in an image; [2 marks]
    iv. convert a color image (in RGB format) to a greyscale image while preserving the perceived luminance. [2 marks]
32. In image compression we use three different mechanisms to compress pixel data:
    i. mapping the pixel values to some other set of values;
    ii. quantizing those values;
    iii. symbol encoding the resulting values.

    Explain each mechanism, describe the way in which it helps us to compress the image, and describe how the mechanism is implemented in the baseline JPEG compression method. [10 marks]
33. Describe the limitations of human vision in terms of:
    i. spatial resolution,
    ii. luminance,
    iii. color,

    and explain the implications that each of these has on the design of display devices, including numerical estimates of the limits beyond which a human cannot discriminate. [10 marks]