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Closed book, no time limit.
Calculator allowed.
Give complete answers and show all work!

1. (2 points) In computer graphics, a surface which scatters reflected light uniformly in all directions is called a ____________________ surface.
2. (3 points) Forward differencing is a fast way to draw curves; the main limitation of forward differencing is
3. (3 points) What advantage does Bresenham's line-drawing algorithm have over the DDA algorithm and when would that advantage be significant?
4. (4 points) Consider the problem of rasterizing a degree-two implicit curve $f(x, y) = 0$ where x and y are integers and (x, y) refers to the center of a pixel. If $f(0, 0) = 21$, $f(1, 0) = 15$, and $f(2, 0) = 10$, which pixels should be lit on the row $y = 0$? In other words, find all integers x such that $f(x, 0) = 0$.
5. (6 points) A cubic Bézier curve has control points with Cartesian coordinates (2,5), (302,137), (567,200), (825,326). It is drawn in a window with center (0,0) and half-widths $w_x = 1000$, $w_y = 1000$ and mapped to a window with center $(0, 0)$ and half-widths in pixels of $v_x = 500$, $v_y = 500$. What step size should be used in rasterizing this curve?

6. (3 points) Normalize the vector $(4, -3, 12)$.

7. (3 points) What is the cosine of the angle between the vectors $(1, 2, 3)$ and $(3, 2, -1)$?

8. (2 points) An array of pixels is called a ____________________.

9. (2 points) The word *pixel* is short for ____________________ ____________________.

10. (2 points) The *resolution* of a frame buffer means ____.

11. (2 points) A CRT for which the electron beam can be moved directly from any position to any other position on the screen is called a ________________________________ CRT.

12. (2 points) The rate at which pixels are redrawn in a CRT is called the ________________________________.

13. (5 points) The operation of rotating by an angle of 90° about an axis that has a direction vector of $(0, .6, .8)$ and that passes through the point $(4, 3, 0)$ can be performed using a single 4×4 matrix that is a concatenation of five elementary 4×4 matrices: $M_1 M_2 M_3 M_4 M_5$. Describe precisely in words what those five matrices do (such as "translate by (1,2,3)" or "rotate 90° about the x-axis. You do *not* need to show the contents of the matrices. The order in which the concatenation occurs is $M_1 M_2 M_3 M_4 M_5$.

    M_1:____

    M_2:____

    M_3:____

    M_4:____

    M_5 :____

14. (3 points) What advantage is there to flood fill using 4-connected regions rather than 8-connected regions?

15. (3 points) How long is the projection of the vector (3,3,0) onto the vector (8,9,12)?

16. (6 points) A coordinate system (u,v,w) has an origin at (4,5,5) and the u-axis has direction vector (8,9,12)/17; the v axis has direction vector (0,12,-9)/15, and the w-axis has direction vector (-75,24,32)/85. What are the (u,v,w) coordinates of a point whose (x,y,z) coordinates are (19,20,5)?

17. (5 points) Express in a 3X3 matrix the window-viewport mapping for a window centered at (10,20) with half widths 15 and 10; and a viewport centered at (100,200) with half widths 300 and 200.

18. (4 points) What is the unit normal vector for the triangle with vertices (1,2,3), (3,2,1) and (2,3,-1)?

19. (3 points) Would that triangle be back-faced culled if viewed from (0,0,100)?

20. (3 points) What is the area of the triangle with vertices (1,2,3), (3,2,1) and (2,3,-1)?

21. (6 points) A line segment begins at pixel $(1, 1)$ and ends at pixel $(8, 4)$. Which other pixels will the Bresenham algorithm turn on?

22. (6 points) A line segment begins at pixel coordinates $(1.2, 1.9)$ and ends at pixel coordinates $(7.9, 8.3)$. Which pixels will the DDA algorithm turn on? (using floating point arithmetic, and assume that pixel centers have integer coordinates).

23. (6 points) What is the 3×3 transformation matrix for performing a rotation of 180° about the point $(2, 3)$? (This is a 2D rotation.)

24. (6 points) In Figure 1, if $\mathbf{E} = (4, 14, 7)$, $\mathbf{A} = (1, 2, 3)$, and $\mathbf{Up} = (0, 1, 0)$, find the unit vectors $\mathbf{u}$, $\mathbf{v}$, and $\mathbf{w}$.

    $\mathbf{u} =$ ______________________ $\mathbf{v} =$ ______________________ $\mathbf{w} =$ ______________________

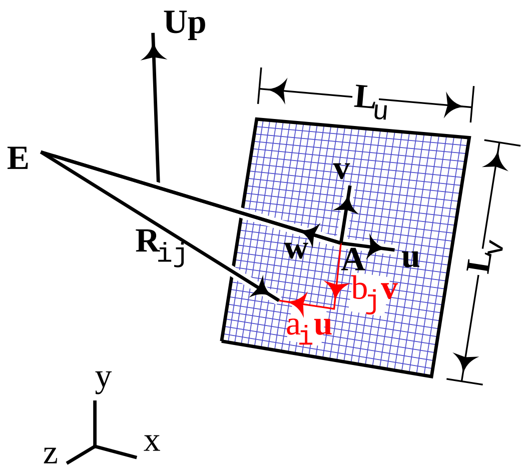

Figure 1: Eye coordinate system

25. (5 points) For a certain Bézier curve, $\mathbf{P}(0.0) = (0, 0)$, $\mathbf{P}(0.1) = (1, 2)$, $\mathbf{P}(0.2) = (2, 3)$, and $\mathbf{P}(0.3) = (4, 4)$. Find $\mathbf{P}(0.4)$.

26. (5 points) For a Bézier curve with control points $\mathbf{P}_0 = (0, 0)$, $\mathbf{P}_1 = (8, 8)$, $\mathbf{P}_2 = (16, 24)$, and $\mathbf{P}_3 = (16, 0)$, find the point on the curve with parameter value $t = \frac{1}{2}$.