CS 551/645: **Introduction to Computer Graphics**

Midterm Examination

Name: ______________________ Login: ___________ Taking 551 or 645: ______

Honor Pledge: This is a closed-book, closed-notes, closed-computer, closed-neighbor exam. Please sign the honor pledge: **Upon my honor, I have neither given nor received unauthorized aid on this exam.** Signed, ______________________.

Instructions: The exam is intended to take 20-30 minutes; you have the full class period to work on it. Be aware that the problems on the last page are worth more and will probably take longer than the rest. 80 total points.

Display Technologies:

1. (4 pts) Name two disadvantages of vector CRT displays versus raster displays.

   (a) Can only draw wireframe

   (b) Lines must be refreshed frequently or they fade, causing visible flicker. This limits the complexity of the scene that can be drawn.

2. (3 pts) On most computers, the framebuffer is implemented as a separate memory bank from the computer's main memory. Why?

   The framebuffer must be fast, because every single pixel must be scanned out 30 or more times per second. This also causes extra memory traffic that would clutter up the system bus if the framebuffer were in main memory. Framebuffers are often dual-ported for these reasons.

3. (4 pts) In a *TrueColor* (24-bit) framebuffer, each pixel may be one of 16,777,216 colors. How many colors can a pixel be in a *PseudoColor* (8-bit) framebuffer?

   Pixels can be any of 16,777,216 colors, but only 255 colors are displayed at once.

[/ 11 pts]

Mathematical Foundations

4. (5 pts) Given a set of vectors $\mathbf{v}_1$, $\mathbf{v}_2$, $\mathbf{v}_3$,… $\mathbf{v}_n$, what defines whether the set is *linearly independent*?

   If the only set of coefficients $\alpha_1, \alpha_2, \ldots, \alpha_n$ such that
   $$\alpha_1 v_1 + \alpha_2 v_2 + \cdots + \alpha_n v_n = 0$$
   is $\alpha_1 = \alpha_2 = \ldots = \alpha_n = 0$, the set is linearly independent.

   Also acceptable: if the dot (inner) product of all pairs of vectors equals 0, the set is linearly independent.

5. (4 pts) Using matrix-vector notation, define the *dot product* between two 3-dimensional vectors **u** and **v**.

$$\mathbf{u} \bullet \mathbf{v} = \begin{bmatrix} \mathbf{u}_x & \mathbf{u}_y & \mathbf{u}_z \end{bmatrix} \begin{bmatrix} \mathbf{v}_x \\ \mathbf{v}_y \\ \mathbf{v}_z \end{bmatrix}$$

Color and Perception

6. (5 pts) The CIE introduced three hypothetical light sources X, Y, and Z. Why were the spectra of those light sources chosen as they were?

   So that any wavelength λ could be perceptually matched by positive mixing coefficients of the three sources X, Y, and Z.

7. (2 pts) What causes color blindness?

   The lack of one or more of the three types of cones (S, M, or L).

8. (5 pts) Define *metamers*.

   Perceptually identical color sensations caused by different spectral distributions.

[/ 21 pts]

Rasterization

9. (8 pts) Edge walking triangle rasterizers calculate the vertical edges of a triangle to determine the first and last pixels of each *span*. Give one reason why it would be incorrect to use Bresenham's line-drawing algorithm directly to determine these pixels.

   Okay answer (5 pts): Bresenham's algorithm assumes integer endpoints

   Better answer (8 pts): Bresenham's algorithm finds the pixels closest to the ideal line, but we want the pixels closest to the line on a given side. Some pixels lit by Bresenham's algorithm will be outside the triangle.

10. (5 pts) Could the technique of edge equations be used to rasterize a polygon of more than three sides? Why or why not?

    Only if the polygon was convex, since the edge equations each separate the plane into two *half-spaces,* and the intersection of half-spaces is always convex.

Clipping

11. (6 pts) Under what conditions can we (a) trivially **reject** a line segment in the Cohen-Sutherland line-clipping algorithm? When can we (b) trivially **accept** a line segment?

    (a) If the bitwise AND of the outcodes of both endpoints is non-zero, the line is entirely to one side of the viewport and we can trivially reject it.

    (b) If the outcodes of both endpoints are zero, the entire line is within the viewport and we can trivially accept it.

12. (8 pts) Each stage of the Sutherland-Hodgman polygon clipping algorithm classifies the current vertex *p* and previous vertex *s* of the input polygon against a given plane. What will the output of the algorithm be for each of the four basic input cases below:

    (a) *s* inside plane and *p* inside plane:
    emit *p*

    (b) *s* inside plane and *p* outside plane:
    find intersection *i* of line with plane and emit *i*

    (c) *s* outside plane and *p* outside plane:
    do nothing

    (d) *s* outside plane and *p* inside plane:
    find intersection *i*; emit *i* followed by *p*

[/ 27 pts]

Transformation Matrices

13. (10 pts) Calculate a 3x3 rotation matrix which rotates points about the vector **A** = [1,1,1] by 90º. Show your work.

14. (3 pts) Name one reason homogeneous coordinates are convenient for computer graphics.

    Allows us to encode translation as a matrix and composite with other transformations such as rotation and scale.

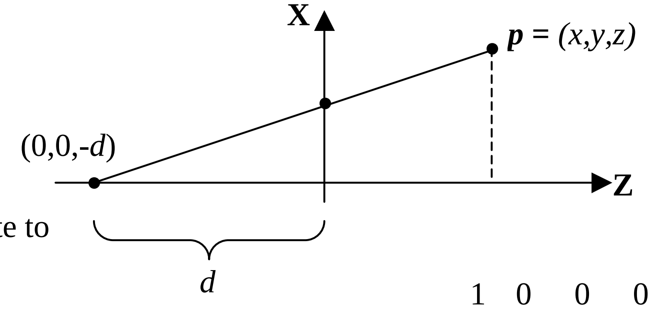
    Also acceptable: allows us to encode projection (which involves a divide by z) as a matrix and composite with other transformations.

15. (8 pts) In class we constructed a 4x4 projection matrix which performed perspective projection along the **Z** axis onto a view plane at Z = *d* for a viewpoint centered at the origin (0,0,0). There are advantages to an alternative formulation in which the viewpoint is at point (0,0,-*d*) and the view plane is at the origin (i.e., the view plane is just the XY plane). Diagram this situation and construct the corresponding 4x4 projection matrix.

$x' = x \cdot d/(z+d) = x / (1 + z/d)$

$y' = y \cdot d/(z+d) = y / (1 + z/d)$

$z' = 0$



We want our final homogeneous coordinate to be $[x,y,0,1+z/d]^T$.

The 4x4 matrix which transforms $[x\ y\ z\ 1]^T$ to $[x\ y\ 0\ 1+z/d]^T$ is:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1/d & 1 \end{bmatrix}$$

[/ 21 pts]