

CMSC 435/634 Computer Graphics Midterm Review

These questions are only a study guide. Questions found here may be on your exam, although perhaps in a different format. Questions NOT found here may also be on your exam. Pay attention to homework and project questions. Note that there will be questions about OpenGL programming in the midterm.

For the midterm:

- Closed book
- One double-sided sheet of letter-size notes permitted
- Everything covered in lecture including **Math, Transforms, Viewing, Pipeline, Mesh, Curves, Animation, and Rasterization (Chapters 1-15 excluding the chapters we did not talk about in class.)**.

Before the exam:

- Make sure you understand the concepts related to the key objectives of each lecture.

During the exam:

Strategy: Read through the entire question before you begin it. If you get bogged down on a question, go on and come back later. Even if you don't think you know the entire answer to a question, do what you can in order to get partial credit. If something isn't clear to you, ask.

Odds and Ends, Some OpenGL

1. What is the most amusing bug you've written in this class?
2. Name one graphics fact about Ivan Sutherland (do some research yourself).
3. Where is the default (0, 0) on the screen defined by OpenGL? Where is the point (100, 120) going to appear on a screen with a resolution of (640, 480)? You can answer these questions by drawing in the screen coordinates.

Concepts and Terminology

4. Give a short (5 - 10 words) or write an equation if appropriate to define each of the following:

Dot product; cross product; matrix multiplication; plane normal; triangle normal; line equations; interpolation from a line equation; parametric equation, quadratic equation, homogeneous coordinates; affine transformation; orthogonal (parallel) projection; perspective projection; rasterization; five matrices for computing the pixel coordinates for an object in 3D; vector normalization; graphics pipeline; viewing frustum; Bezier curve; Bezier polygon; line equations; cubic; quadric; composing transform; transform; rotate, scale, translation;

Example questions:

- a. Write an implicit equation for a sphere at the origin with radius R.

- b. Write a parametric equation for a sphere at the origin with radius R.
- c. What is the dot product of two vectors, in terms of the length of each vector and the angle between them?
- d. What is the length of the cross product of two vectors, in terms of the length of each vector and the angle between them?
- e. Give two reasons we use homogeneous coordinates for transformation matrices

Display

5. What is an image on your computer screen? How is it computed in the graphics pipeline?
6. What is a pixel?
7. Why do we use RGB color? What do R, G and B stand for?

Rasterization and Pipeline

8. Draw the graphics pipeline.
9. Describe the Bresenham algorithm for line drawing.
10. Describe the rasterization steps for triangles. How would you color a triangle?

Transforms

11. Express the homogeneous 3D transformation defined by the matrix

$$\begin{bmatrix} 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & 3 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

as a sequence of transformations in the following ways:

- A rotation followed by a translation.
- A translation followed by a rotation.

(2) Write the OpenGL code for performing the transformation in (1) using `glRotatef` and `glTranslatef`. Note that the order of these function calls matters.

12. You've been commissioned by the UMBC chess team to create an animation clip for their upcoming series of TV commercials. Your animation will show a chessboard spinning on the tip of the mascot's nose.

a) Rotation angle is a function of time, with the board making three revolutions each second. Initially, the board starts at an angle of zero degrees. Give an equation

describing orientation of the board in degrees as a function of time (with t measured in seconds).

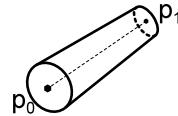
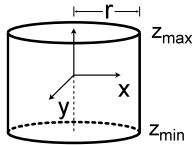
$$\theta(t) =$$

b) Give the 4×4 transformation matrix which transforms the board into the proper orientation at time t , assuming a nose position of $\mathbf{P}(x,y,z)$. Assume that the initial position of the board is centered at the origin. You can assume that rotation happens parallel to the floor (which is the XY plane).

c) What is the value of this matrix when $t = 7.5$ seconds and the mascot's nose is at position $\mathbf{P} = (1, 4, 3)$?

13. Assuming we have drawn a cylinder aligned with the z axis, with radius r from z_{min} to z_{max} .

a) How would you build transform functions to create a cylinder of radius r_2 between points $p_0=(x_0,y_0,z_0)$ and $p_1=(x_1,y_1,z_1)$?



`RiCylinder(r, zmin, zmax)`

`newCylinder(r, x0,y0,z0, x1,y1,z1)`

b) Write the exact OpenGL code for your function `newCylinder(r, x0, y0, z0, x1, y1, z1)`.

14. The OpenGL call, `glRotatef(θ , x, y, z)`, rotates by θ degrees around the vector (x,y,z) through the origin. The rotation is right handed, so if (x,y,z) points toward you, the rotation is counter-clockwise. Write out the 4×4 transformation matrices for `glRotatef(θ , 1, 0, 0)`, `glRotatef(θ , 0, 1, 0)` and `glRotatef(θ , 0, 0, 1)`.

15. Here is an unedited photograph of two normal-sized people:

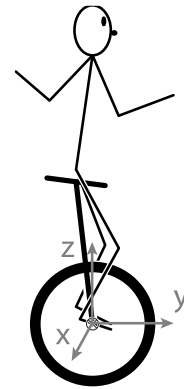


The image above is 450 pixels high, and the two heads measure 90 and 15 pixels high. Assume all heads are 30 cm high. The image on the camera's film plane is 24 mm high.

- (1) If I know that the person in the foreground is 2 meters from the camera, what is the camera's image plane distance (the focal length) and how far away is the other person?
 - (2) If I know that the two people are standing 20 meters apart, what is the image plane distance and how far from the camera is the closer person?
- (Photo courtesy of Seth Teller, who says, "no computers were used to make this picture.")

Viewing

16. You have been asked to model a view from a character on a unicycle. The world coordinates are defined so x and y span the map horizontally and z points up. The unicycle coordinates are centered at the center of the axle, with x pointing right, y pointing forward, and z pointing up.

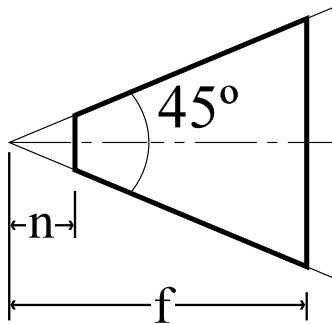


It may be useful for this problem to know the standard math library function $\text{atan2}(y, x)$. This function computes the arctangent of y/x over the full circle, without singularities when $x=0$, and using the signs of both arguments to correctly determine the quadrant of the resulting angle.

- a): If you have a translation function $\text{Translate}(x,y,z)$, and three functions to rotate around the coordinate axes, $\text{RotateX}(\theta)$, $\text{RotateY}(\theta)$, and $\text{RotateZ}(\theta)$ (but NO lookAt transform), what sequence of calls transform from world-space to unicycle-space, leaving the unicycle at a world-space location of (u_x, u_y, u_z) , pointing in the direction (d_x, d_y) ?
- b) If the character's head is at (h_x, h_y, h_z) in unicycle-coordinates with horizontal pan angle of q and vertical tilt angle of f , what sequence of calls will transform view space to world space? In view space, the camera should be at the origin, looking down the $-z$ axis, with x pointing right and y pointing up.

c) What are the 4x4 transformation matrices for Translate, RotateX, RotateY, and RotateZ?

17. This is a side-view of a viewing frustum, with the eye at (0,0,0), x axis pointing out of the page, y axis pointing down, and z axis pointing to the right. This frustum has a 45° field of view and near and far planes at n and f :



- What are the eight corners of the frustum?
- What are the clipping cases? Give an example of each.

Mesh

- Describe three applications that make use of mesh.
- What are the triangles and index triangles representations? Which one is better and why?
- List at least two ways to draw triangles in OpenGL and the amount of memory uses for each method.

Curves

- In a lecture, we derived the method for transforming curves in canonical form into the polynomial curves. Now for a curve of $f(u) = -12u^2 + 12u + 1$, find the Bezier representation of degree 3 in the interval $[1, 4]$ and draw the Bezier polygon.
- Given four control points, know how to draw a cubic curve.
- Describe continuity and the five continuities we defined in class up to the 2^{nd} order. What do each of these five continuities imply? What are the two large classes and which one has less constraints?