**CSCE 4813 - Computer Graphics**  
**Midterm Exam - Fall 2008**

**Instructions:**

This is a 70 minute closed book exam. One 8.5 x 11 page of notes are allowed. Calculators can be used for numerical calculations only (not as electronic notebooks). Please write neatly and sign your name to your exam. Raise your hand if you have any questions.

**Name: ____________________**

**Geometric Objects (20 points)**

Assume that you have been hired to generate a geometric model of part of an automobile. The designer has said that the surface should have the same shape as \( z(x,y) = ax^2 + by \), for \( x \) values between -5 and 5, and \( y \) values between -10 and 10.

- Describe how you would model this surface using 100 rectangular polygons. In particular, how would you calculate the \((x,y,z)\) coordinates of the vertices of these polygons? Draw diagrams and write pseudo-code as necessary to explain your approach.

- In order to generate a realistic image of this surface, we need to know the surface normal \( N \) at each polygon vertex. Describe one method for calculating \( N \) at position \((x,y)\). Again, use diagrams and equations to explain your solution.

**Geometric Transformations (30 points)**

We have discussed rotation, translation and scaling transformations in class. For this question, we will be using the following notation:

- \( R(\theta, z) \) denotes a rotation by \( \theta \) degrees around the \( z \)-axis.
- \( T(dx, dy, dz) \) denotes a translation by \((dx, dy, dz)\) units.
- \( S(sx, sy, sz) \) denotes a scaling by \((sx, sy, sz)\) units.

- All three of these operations can be implemented using matrix multiplication using homogeneous coordinates. Give the 4x4 matrices for rotation, translation and scaling assuming post multiplication.

- We can combine transformations by multiplying the matrices above. Give one example where the order of operations does not matter (where matrix \( M \times N \equiv N \times M \)) and one example where the order of operations does matter (where matrix \( M \times N \neq N \times M \)).

- What sequence of transformations is necessary to rotate an object by \( \theta \) degrees around the \( z \)-axis with the center of rotation at the point \((a,b,c)\).
Computer Viewing (20 points)

In OpenGL (and many other graphics APIs) images are created using an ideal pin-hole camera model with the center of projection at the origin (0,0,0) and the camera pointing in the –z axis, with an up direction in along the y-axis. All (x,y,z) points in the scene are projected on the z=d plane, so they have coordinates (xp, yp, d). This is illustrated below.

- Using this information, derive the formulas for perspective projection (solve for xp and yp in terms of the other variables above).
- What do you think happens to the image if we project on the plane z = 2*d? What do you think happens to the image if we project on the plane z = -d?

Computer Shading (20 points)

In the Phong shading model, the amount of light reflected from a surface has three components: the diffuse term D, the specular term S, and the ambient term A. When the light source is pure white, the output intensity of light is given by: \( I = kd * D + ks * S + ka * A \), where (kd, ks, ka) describe the reflection properties of the object.

- Describe how the diffuse term D is calculated? What additional information about the object or the environment do we need? Use diagrams and equations to explain.
- Describe how the specular term S is calculated? What additional information about the object or the environment do we need? Use diagrams and equations to explain.

Other Topics (10 points)

Describe one other topic from this class that you found to be interesting and/or surprising. What was your favorite part?