University of California San Diego
Department of Computer Science
CSE167: Introduction to Computer Graphics
Midterm Examination
Thursday, October 25, 2012

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Name:_____

Please write your name or initials at the top of every page before beginning the exam.

Please write your answers on these sheets and include all steps of your derivations in your answers. If your answer is a mix of correct and wrong arguments we will consider deducting points for incorrect statements. You may not use calculators, notes, textbooks or other materials during this exam, except for one single sided, hand-written 3x5 inch index card. There are ten questions for a total score of 100 points.

Good luck!

Do not write below this line

Exercise	Points
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total	

1. Linear Algebra (10 Points)

a) Given the following two vectors:

$$a = \begin{bmatrix} 3 \\ 4 \\ 0 \end{bmatrix} \qquad b = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

Compute the following (3 points):

The magnitude of **a**:

The magnitude of **b:**

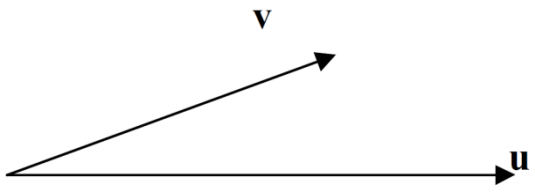
The dot product of **a** and **b:**

b) Consider a homogeneous affine transformation matrix M, constructed from columns a, b, c and d:

$$\begin{bmatrix} a_x & b_x & c_x & d_x \\ a_y & b_y & c_y & d_y \\ a_z & b_z & c_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Write the result of transforming $\begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$ in terms of **a**, **b**, **c** and **d**. (2 points)

c) Given the unit vector [ux, uy, uz] and another vector [vx, vy, vz], what two useful quantitative measures does the dot product of u and v represent? Label the diagram. (3 points)



d) If the vectors, u and v from the previous example are coplanar with this sheet of paper, does the cross product v X u extend towards the reader or away? (2 points)

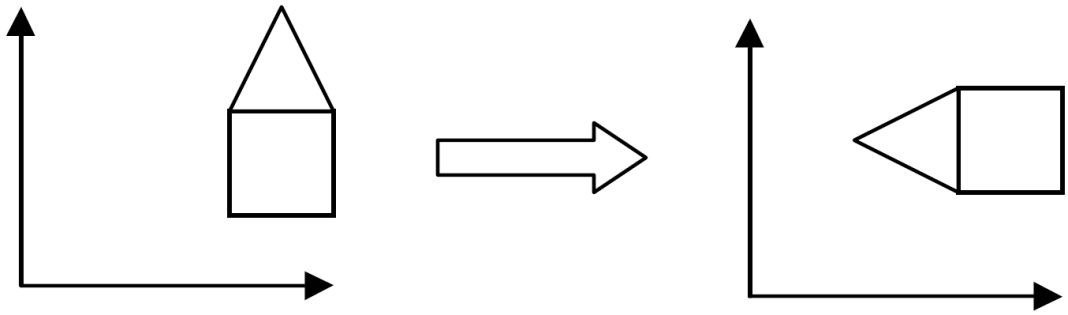
2. Matrices (10 Points)

a) Why do we use a 4x4 homogenous coordinate transformation matrix when describing translations, rotations, and scales, etc.? (2 points)

b) Below are two 4x4 homogenized transformation matrices. Which one will do a uniform scale making object 2x larger? What does the other do? (2 points)

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 4 \end{bmatrix} \qquad \begin{bmatrix} 6 & 0 & 0 & 0 \\ 0 & 6 & 0 & 0 \\ 0 & 0 & 6 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

c) Provide a 3x3 matrix that will compute the new vertices of a planar house centered at [10, 5] after a rotation of 90 degrees about its center (6 points).



3. Projection (10 Points)

a) Explain the difference between “object coordinates”, “world coordinates”, and “camera coordinates”. (2 points)

b) “Camera transformations are done backwards and in reverse order.” Explain. (2 points)

c) In what way is orthographic projection a special case of perspective projection? (2 points)

d) A common method for specifying the camera position is to give a look-from point F, a look-at point A, and an up-vector U.

Suppose

F = (1,0,1), A = (0,0,0) and U = (0,1,0)

Derive a 4x4 transformation matrix that may be used to view the world from this position. (4 points)

4. View Volumes (10 Points)

Given the following typical GLUT reshape function:

```
void reshapeCallback(int w, int h)
{
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluPerspective(45.0, float(w)/float(h), 1.0, 100.0);
}
```

a) What does the reshape function do when you use the mouse to reshape the window? (2 points)

b) What would happen if you remove the glViewport(0, 0, w, h) command from the reshape function, compile the program, and use the mouse to reshape the window? Why? (2 points)

c) What would happen when you use the mouse to reshape the window if the reshape function had glViewport(0, 0, w, h) as the only single statement in it? Why? (2 points)

d) What would happen when you use the mouse to reshape the window (at least twice) if we remove the glLoadIdentity( ) statement from the reshape function? Why? (2 points)

e) What would happen if you change the 45.0 in the gluPerspective function to 90.0? (2 points)

5. Culling (10 Points)

For each of the following culling strategies, describe what the culling criterion is and briefly describe in one sentence an approach for a possible culling algorithm.

a) View frustum culling (2 points)

b) Occlusion culling (2 points)

c) Small object culling (2 points)

d) Backface culling (2 points)

e) Degenerate culling (2 points)

6. Rasterization (10 Points)

a) Discuss the z-buffer algorithm. Describe the algorithm. What is its purpose? How is it implemented? (2 points)

b) What are the z-buffer algorithm's advantages over competing algorithms? What are its disadvantages relative to competing algorithms? (Be specific about what competing algorithms you are discussing.) (2 points)

c) Before we can begin drawing with a z-buffer algorithm we need to initialize the values in the z-buffer. Why? What would be a reasonable value for initializing the z-buffer? (2 points)

d) OpenGL includes a far clipping plane, limiting the distances of visible objects. This seems unnatural. Why is it done? (2 points)

e) Using a simple example explain why the Painter's Algorithm may fail to produce an image with the correct occlusions depicted. (2 points)

7. Color (10 Points)

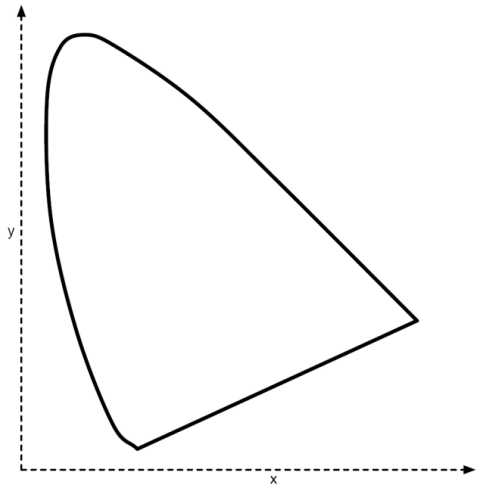
a) Define metamers. (2 points)

b) Describe the difference between rods and cones. (2 points)

c) What is the tristimulus theory, and how does it help us in Computer Graphics? (2 points)

d) Can a computer monitor produce all the colors we see in the world? Why or why not? (2 points)

e) The following diagram shows the the x-y plane of the CIE color space. Mark and label one plausible location each for the red, green, and blue basis colors. Indicate the color gamut for the color basis you have shown. (2 points)



8. Lighting (10 Points)

a) Name two differences between directional lights and point lights. (4 points)

b) Assume that there is a point light at position p that is illuminating a point v on a surface. Explain why the intensity of the light is proportional to $1/||\mathbf{p}-\mathbf{v}||^2$, i.e., one over the squared distance between the light source and the point on the surface. (3 points)

c) Which two additional parameters do OpenGL spot lights have compared to point lights? (3 points)

9. Shading (10 Points)

a) In the diagram below, indicate the point on the line that will appear brightest to the observer if the line acts like a diffuse reflector. (2.5 points)

b) In the diagram below, indicate the point on the line that will appear brightest to the observer if the line acts like a specular reflector. (2.5 points)

c) The diagram below shows a triangle with vertices labeled a, b, and c. Several locations have been indicated with circles. The list of numbers to the left contains triples of numbers, named A through E, representing the barycentric coordinates of these circles. Label each of the circles with the letter of the corresponding number triple. (1 point each)

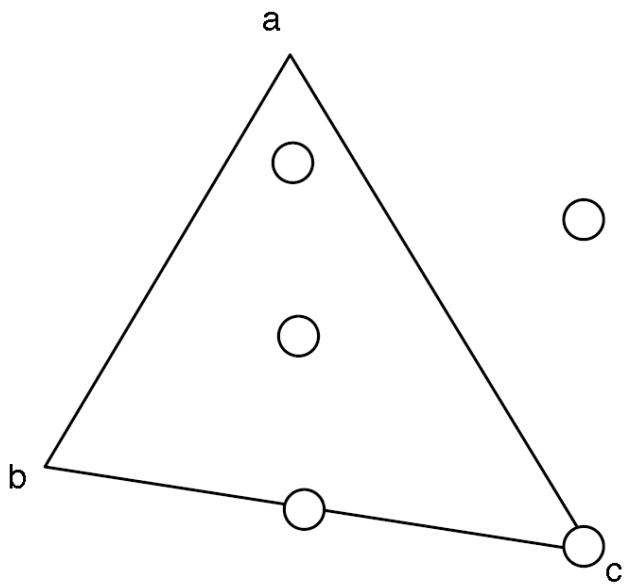
A: 0, 0, 1

B: 0.333, 0.333, 0.333

C: 0, 0.5, 0.5

D: 0.75, -0.5, 0.75

E: 0.8, 0.1, 0.1



10. Shader Programs (10 Points)

a) GLSL has three qualifiers that specify communications paths between a shader and another shader, or the application: `attribute`, `uniform`, `varying`. Explain what each of them means. (6 points)

b) Assuming that both vertex and fragment programs have been loaded for rendering a triangle. How many times will the vertex program get executed, how many times the fragment program? (4 points)