University of California San Diego
Department of Computer Science
CSE167: Introduction to Computer Graphics
Fall Quarter 2015
Midterm Examination #1
Thursday, October 22nd, 2015
Instructor: Dr. Jürgen P. Schulze

Name:_____

Your answers must include all steps of your derivations, or points will be deducted.

This is closed book exam. You may not use electronic devices, notes, textbooks or other written materials.

Good luck!

Do not write below this line

Exercise	Max.	Points
1	10	
2	10	
3	10	
4	10	
5	8	
6	10	
7	10	
8	12	
Total	80	

1. Geometric Transformations (10 Points)

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

- R(theta, axis) denotes a rotation by theta degrees around the specified (x, y, z) axis. Use the right hand rule for the direction of the rotation.
- T(dx, dy, dz) denotes a translation by (dx, dy, dz) units.
- S(sx, sy, sz) denotes a scaling by (sx, sy, sz) units.

a) Start with a 2x2 square in the x/y plane, centered at the origin. Draw a picture that shows what happens to this square when you first apply rotation R(90 , z) followed by a scaling of S(1, 2 , 1). Draw each step. What happens if you reverse the order of operations? Is this true for all R,S? Explain. (4 points)

b) Draw a picture that shows what happens if you translate a 2x2 square by T(1 , 1 , 0) followed by a rotation of R(45 , z). What happens if you reverse the order of operations? Is this true for all R,T? Explain. (3 points)

c) Sometimes we want to scale an object about an arbitrary center point (cx, cy, cz) to simplify user interaction or to get different visual effects. Use diagrams and equations to show how to perform this composite geometric transformation. (3 points)

2. Graphics Pipeline (10 points)

a. Camera Space
b. Image Space
c. Inner Space
d. Canonical View Volume Space
e. Object Space
f. Outer Space
g. Projective Space
h. World Space

Select the correct spaces (=coordinate systems) from above and list them in the order that we expect each vertex to go through in the traditional transformation process:

Fill in letters here: 1. ____ 2. _____ 3. _____ 4. _____ 5. _____

3. Projection (10 Points)

The goal of projection is to transform three-dimensional object coordinates (x, y, z) into two-dimensional screen coordinates (x', y').

a) For perspective projection, assume the center of projection is at (0, 0, 0) and the image plane is at z=d. What are the formulas for calculating (x', y') in terms of (x, y, z) and d?

b) Draw a side view diagram to illustrate what happens to the projected image if we move an object closer to the image plane. Will the image become larger or smaller?

c) For parallel projection, assume the imge plane is at z=d. What are the formulas for calculating (x', y') in terms of (x, y, z) and d?

d) Draw a side view diagram to illustrate what happens to the projected image if we move an object closer to the image plane. Will the image become larger or smaller?

4. Coordinate System Transformation (10 Points)

Given a point p with *camera space* coordinates p = (2, 1, 1).

In addition, camera space has its origin at $(2,\frac{1}{\sqrt{2}},-\frac{1}{\sqrt{2}})$ in *world space*, and the basis vectors of camera space have *world coordinates* $(0,1,0)$, $\left(\frac{1}{\sqrt{2}},0,\frac{1}{\sqrt{2}}\right)$, $\left(\frac{1}{\sqrt{2}},0,-\frac{1}{\sqrt{2}}\right)$.

What are the *world space* coordinates of p?

5. Illumination (8 points)

An important component of the Phong Reflection Model is the phenomenon of incident light reflecting off of a material surface.

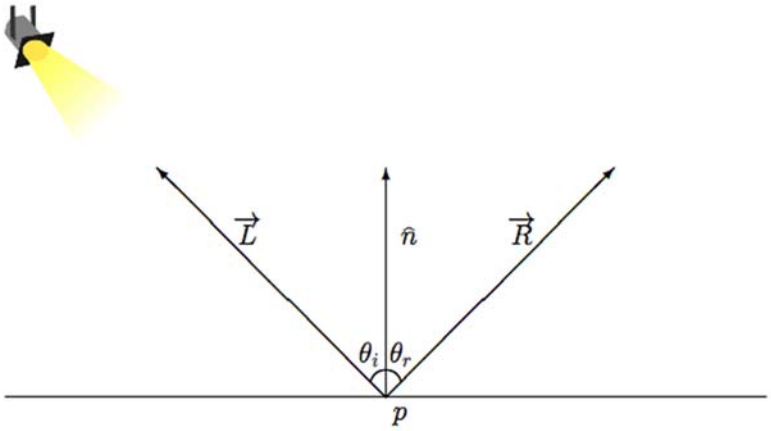
a) Given a world space light position *l*, a world space hit point *p*, and a world space normal vector *n*:

$$\dot{l} = [-10, 2, 7]$$

$$\dot{p} = [-6, 4, 3]$$

$$\hat{n} = [\frac{6}{10}, \frac{8}{10}, 0]$$

Find the reflection vector *R*. Show all work. (6 points)



b) What is the relationship between angles $\boldsymbol{\theta}_i$ and $\boldsymbol{\theta}_r$? (2 points)

6. Depth Buffer (10 Points)

a) Describe the depth buffer (z-buffer) algorithm. What is its purpose? Write down pseudo-code for the depth test. (4 points)

b) What happens visually on the screen if the resolution of the depth buffer (i.e., the number of bits available to store the depth) is insufficient? (2 points)

c) In the context of the depth buffer, what is the role of the near and far planes? (2 points)

d) Name an advantage and a disadvantage the z-buffer algorithm has over the Painter's Algorithm. (2 points)

7. Lights (10 Points)

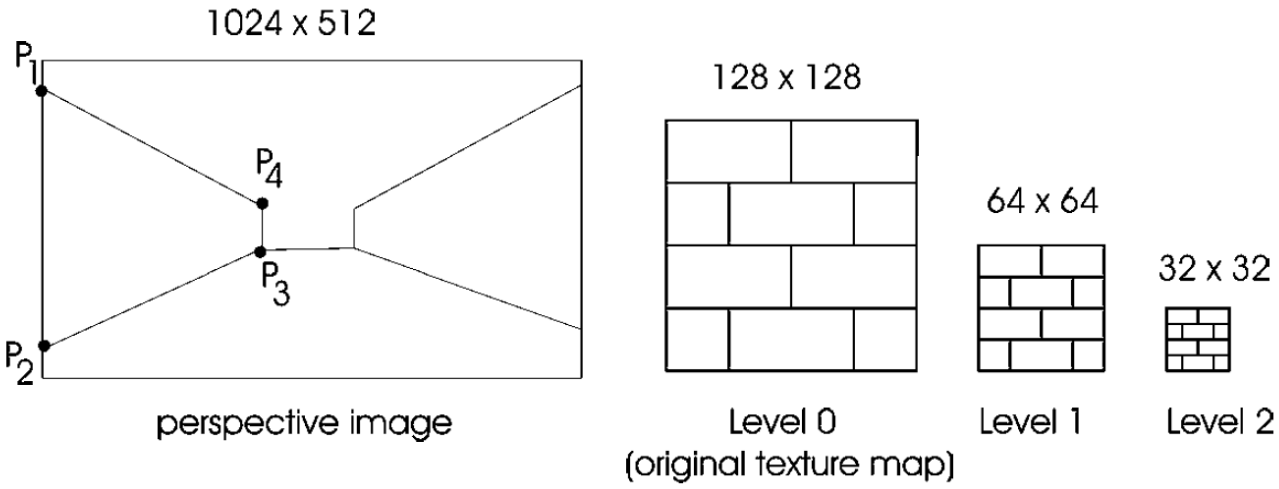
a) Name two differences between directional lights and point lights. (4 points)

b) Name the three additional parameters OpenGL spot lights have compared to point lights? (3 points)

c) How do the three distance attenuation options for point lights in OpenGL differ from one another? (3 points)

8. Mip-Mapping (12 points)

Suppose we have a brick wall that forms the left-hand wall of a corridor in a maze game, as shown in the image below, and it is defined (in world coordinates) by points P_1, P_2, P_3, P_4. Assume that the brick wall is to be 16 bricks high and 200 bricks long.



a) Using the height of the brick wall as seen in the image, estimate (with derivation) how many texels of the original texture map a screen pixel covers, both for near points on the wall, i.e., on the edge P_1P_2, and at distant points on the wall, i.e., on the edge P_3P_4. (3 points)

b) In the perspective image above, sketch approximately what regions of the wall will use each of the levels of the mip-map image pyramid on the right (use nearest-mipmap interpolation, not trilinear mipmapping). (3 points)

c) Unrelated to the above image: How many texel values have to be read to perform nearest neighbor texture filtering, bilinear texture filtering, and trilinear mipmapping? (3 points)

d) In which order are the texel values in each of the three methods above being averaged? (3 points)