University of California San Diego
Department of Computer Science
CSE167: Introduction to Computer Graphics
Spring Quarter 2016
Midterm Examination #2
Tuesday, May 24th, 2016
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!

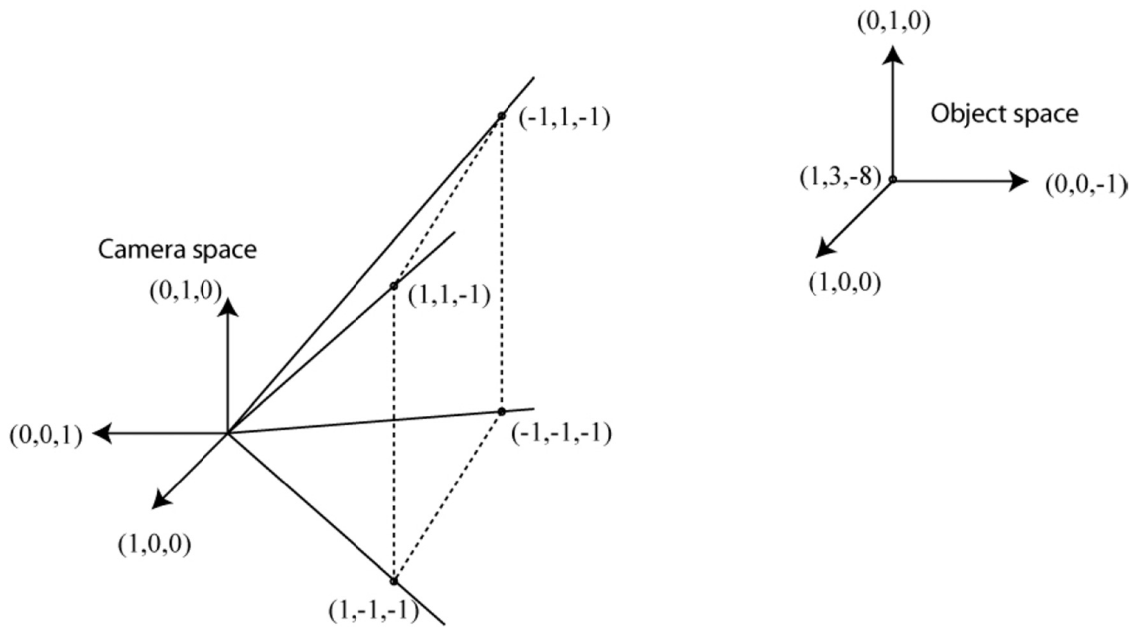
Do not write below this line

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

1. View Frustum Culling (10 Points)

Given the perspective view frustum shown in the figure below. The top bounding plane of the view frustum is determined by the plane going through the points (0, 0, 0), (1, 1,−1), and (−1, 1,−1) in camera coordinates. Note that the other bounding planes will not be relevant to this problem. In addition, there is an object coordinate system defined by basis vectors (0, 1, 0), (1, 0, 0), (0, 0,−1) and the origin (1, 3,−8) in camera coordinates. Note that the order of the basis vectors matters!

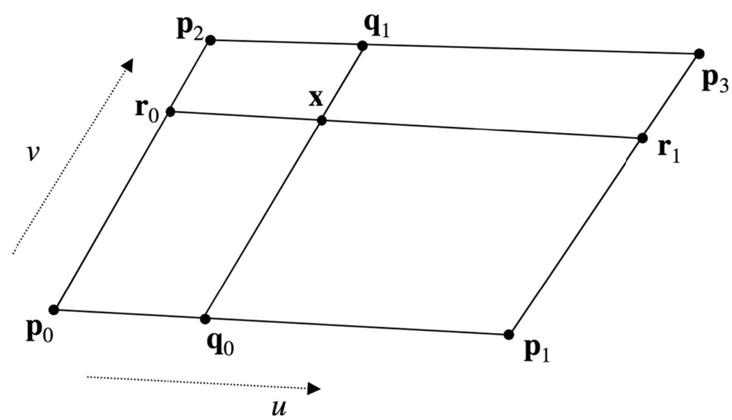
Assume there is an object with a bounding sphere with radius 2 centered at (10, 1, 1) in object coordinates. Determine if this bounding sphere intersects with the top bounding plane of the view frustum. You should do this by transforming the center of the bounding sphere from object to camera coordinates. Then you need to compute the distance from the bounding sphere center in camera coordinates to the top bounding plane.



2. Surface Patches (10 Points)

Evaluating along a line requires an interpolation between two points. This concept can be extended to two dimensions creating a surface patch. Given the values for p_0, p_1, p_2, and p_3 below, find point $x(½, ¼)$ following the steps below.

$$p_0 =< -2,\ -4,\ 8 >$$
$$p_1 =< -6,\ 28,\ -24 >$$
$$p_2 =< 40,\ -14,\ -4 >$$
$$p_3 =< 32,\ -18,\ -12 >$$



a. Find points q_0 and q_1 (6 points):

$$q_0 =< \quad , \quad , \quad >$$

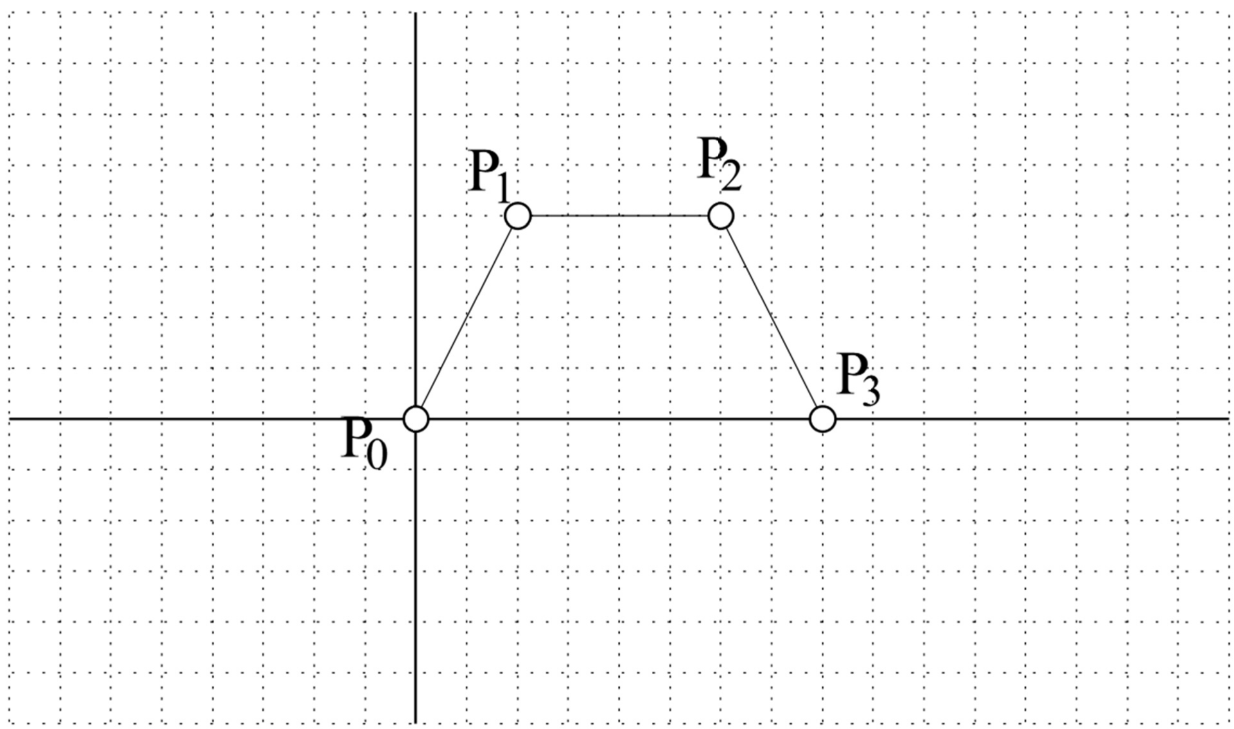
$$q_1 =< \quad , \quad , \quad >$$

b. Find point x (4 points):

$$x =< \quad , \quad , \quad >$$

3. The de Casteljau Algorithm (10 Points)

In the figure below are the control points for a cubic Bezier curve P, defined over the interval [0, 1] by the control points P_0, P_1, P_2 and P_3.

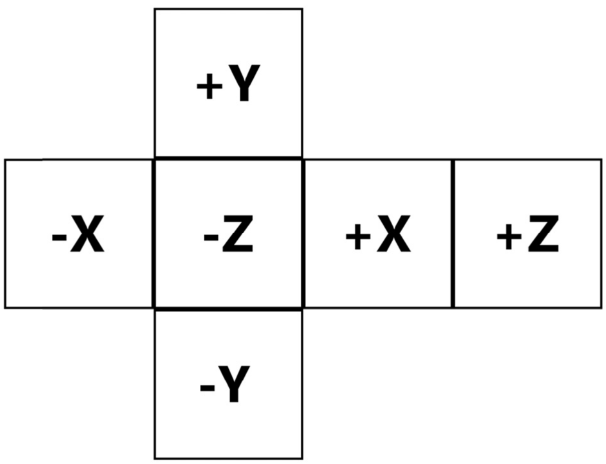


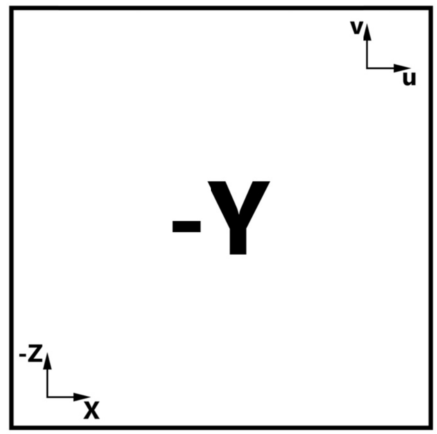
Suppose we want to join another cubic Bezier curve segment Q (defined over the interval [1, 2]) with control points Q_0, Q_1, Q_2 and Q_3, and we wish P and Q to meet with C^1 continuity at parameter value 1 (i.e., the first derivatives should be equal at t=1).

a) In the figure above, draw and label any control points of Q whose placement is forced by the continuity conditions. List any control points of Q whose placement is not forced by the C^1 conditions here: (4 points)

b) Draw the de Casteljau evaluation of P at t=0.5 in the figure above. Label P(0.5) on your drawing. (6 points)

4. Cube Map Sampling (10 Points)
We will be manually sampling a cube map for a skybox of size [-1,1]. A typical arrangement of a cube map texture would look like below, in which an individual texture image has two of the x, y, z axes along it ranging from [-1,1] as well as u, v axes that range from [0, 1] as shown in the negative Y image below. Note that all the u and axes in the six texture images are parallel to one another, and the v axes are parallel to one another as well - in other words, the u axes always point to the right, the v axes point up.





a. If we are sampling light vector (-1, 0, -0.2) on a skybox, which texture image would be used? (2 points)

b. What are the texture coordinates (u and v) that will be used for this light vector on the skybox? Remember that u and v range from [0, 1], whereas our x, y, and z range from [-1, 1]. (3 points)

c. Let's work on the inverse problem: if we are sampling from the negative Z map, and our u, v coordinates are (0.75, 0.25), give the x, y, and z coordinates of the light vector that would result in this sample point? The vector does not need to be normalized. (3 points)

d. So far we assumed our skybox is the canonical size from [-1, 1]. Now we scale our skybox by 500 uniformly, so that its size ranges from [-500, 500]. What are the x, y, and z coordinates from part c in this larger coordinate space? (2 points)

5. Toon Shading (10 Points)

a) Why is toon shading also called Cel Shading? (2 points)

b) Explain the two visual effects we use in toon shading to create the cartoon-style look? (4 points)

c) Explain how the toon shading algorithm detects silhouette edges. (4 points)

6. Procedural Terrain (10 Points)

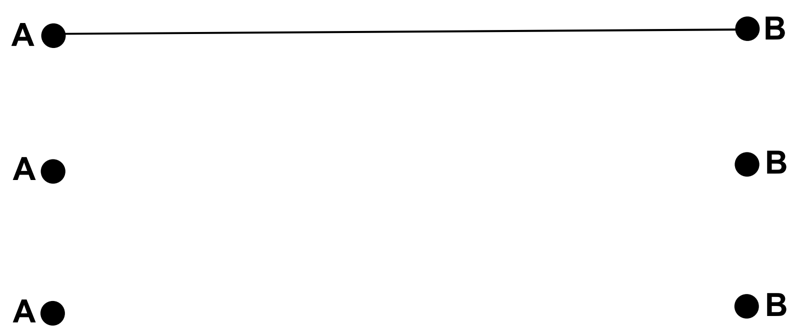
a) Midpoint Displacement Algorithm (4 Points)

Given the initial line below, with end points A and B, draw the first two steps of the midpoint displacement algorithm below it, using offset parameters of your choice. Highlight all end points of the new line segments.

Step 0:

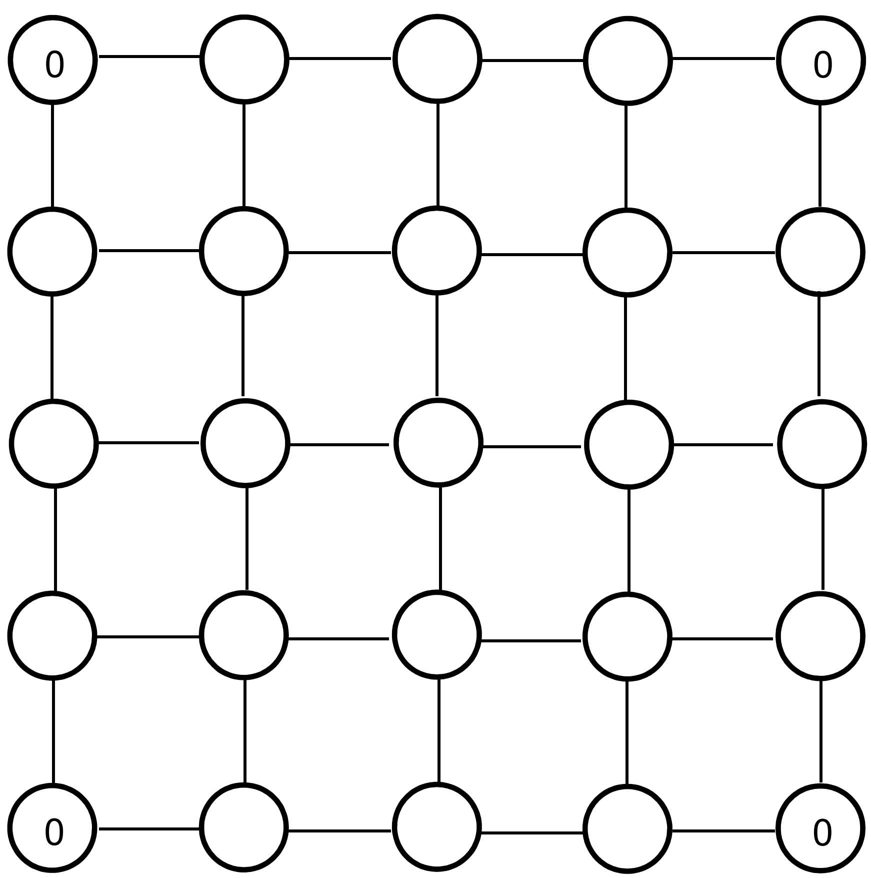
Step 1:

Step 2:



b) Diamond Square Algorithm (6 Points)

In the 5x5 array of terrain nodes below, write in each node the number of the step in which its height is calculated in the Diamond Square Algorithm. The initial Step 0 is already filled in. Hint: there are four more steps.



7. The Mandelbrot Set (10 Points)

The basic formula for the Mandelbrot set is: $Z = Z^2 + C$.

The starting value of Z is 0.

For each point C in the Mandelbrot universe we wish to see, we keep calculating Z until one of two conditions occur:

1. When the absolute value of Z, for a given point, is greater than or equal to 2, that point (and its corresponding square) is said to have **escaped** the Mandelbrot set.

2. If for a point C the value of Z does not escape after **three** iterations of the basic formula, we consider C to be **part** of the Mandelbrot set.

Z and C are normally complex numbers. However, here we will consider them to be real numbers (i.e., no imaginary component).

Determine for the following points C whether they are part of the Mandelbrot set or not. Fill in all 16 blank table cells.

Value of C	Iteration 1	Iteration 2	Iteration 3	Part of Set?
2	6	38	1446	No
1				
0				
-1				
-2				
-3	6	33	1086	No

8. L-Systems (10 Points)

The L-system for the Koch snowflake curve has the following parameters:

- Variables: F
- Constants: +, -
- Start string (Level 0): F - - F - - F
- Production rule: F → F + F - - F + F

Here, F means “draw forward”, + means “turn left 60°”, and - means “turn right 60°”.

The initial orientation of the “turtle” is “up”.

a) Generate the string for level one of the recursion. (4 points)

b) Draw the curves for level 0 and 1 of the recursion. (6 points)