University of California San Diego
Department of Computer Science
CSE167: Introduction to Computer Graphics
Fall Quarter 2017
Midterm Examination #2
Tuesday, November 21st, 2017
Instructor: Dr. Jürgen P. Schulze

Name:______________________________

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

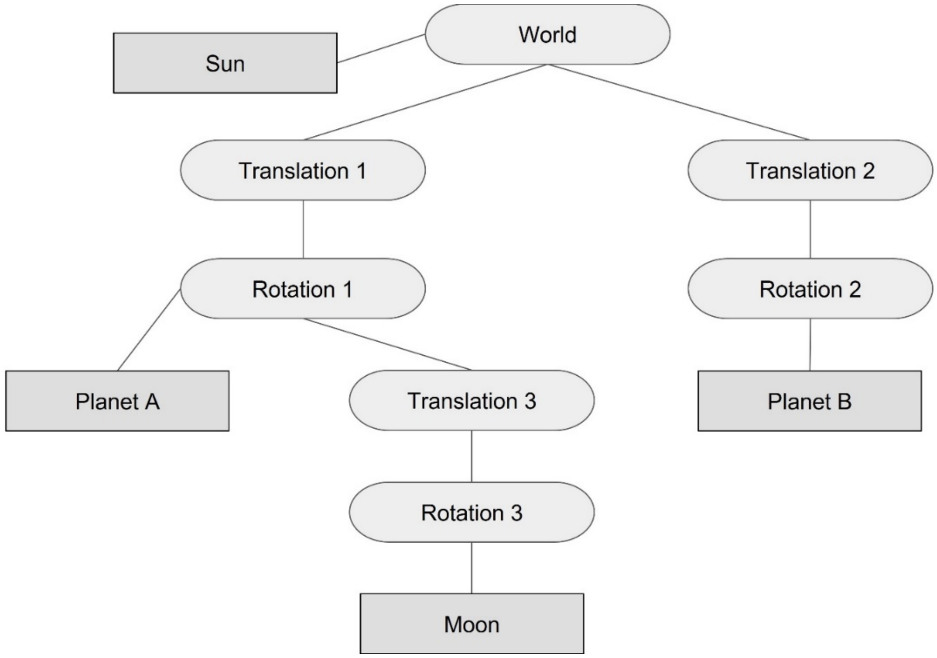
This is closed book exam. You may not use electronic devices, notes, textbooks or other written materials.

Good luck!

Do not write below this line

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

1) Scene Graph (10 Points)



The figure above illustrates a mini solar system. Given the partial source code below, complete the rest for this solar system. Use the function addChild(_____). For example, Translation1.addChild(Rotation1);

```
Sun = new Sun();
Moon = new Moon();
World = new Transform(…);
PlanetA = new Planet('A');
PlanetB = new Planet('B');
Rotation1 = new Transform(…); Translation1 = new Transform(…);
Rotation2 = new Transform(…); Translation2 = new Transform(…);
Rotation3 = new Transform(…); Translation3 = new Transform(…);
```

2) Performance Optimization (10 Points)

For each of the following rendering performance optimization strategies answer the questions: What type of geometry is being optimized? What is the optimization strategy?

a) 2D impostors (2 points)

b) Adaptive mesh resolution (2 points)

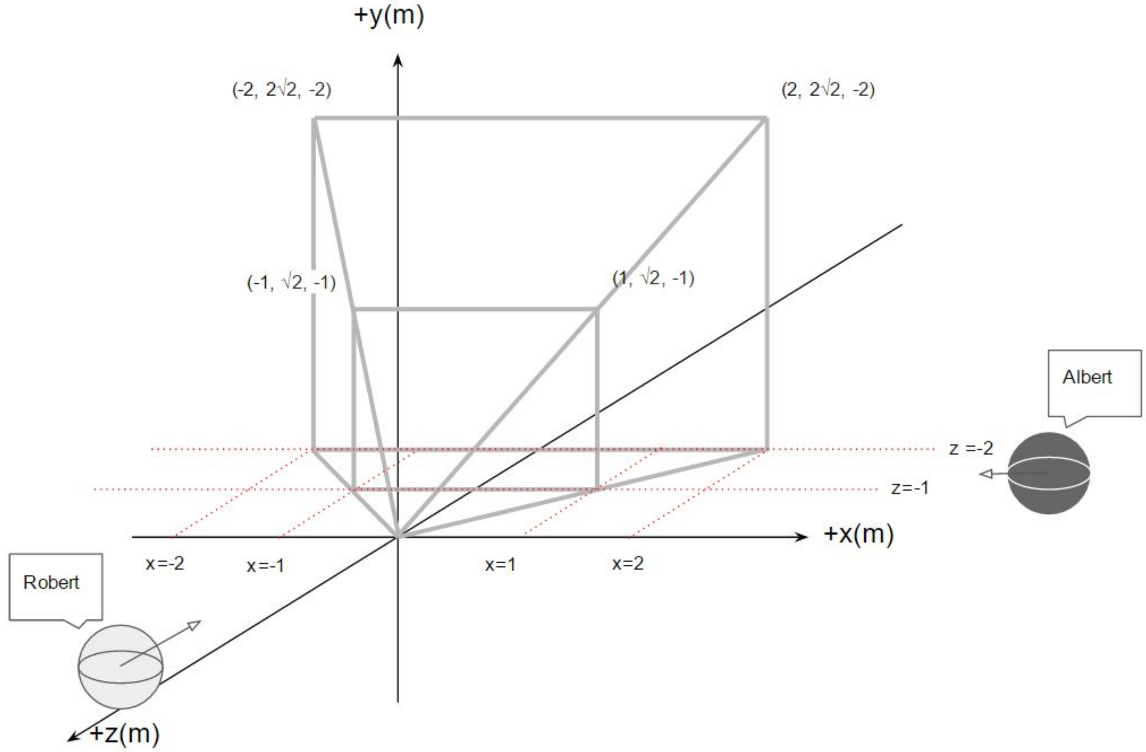
c) Small object culling (2 points)

d) Backface culling (2 points)

e) Hierarchical culling with bounding volumes (2 points)

3) View Frustum Culling (10 Points)

Given a camera at the origin and a view frustum made up of left, right, top, bottom, near, and far planes, as in the picture below:



A robot named Robert is shaped like a sphere of radius 1m. Robert becomes invisible when he is outside the view frustum and the shortest distance from its center to the nearest plane view frustum plane becomes more than its radius. So at the exact moment of intersection, Robert is visible.

a) At t = 0s, Robert is at (0m, 1m, 3m). Robert moves at the rate of (0, 0, -1m) per second. So at t = 1 s, Robert is at (0m, 1m, 2m). When will we see Robert for the first time and when will we see Robert for the last time? (5 points)

b) Robert has a robot friend named Albert. Albert is also shaped like a sphere of radius 1m and is visible under the same conditions as Robert. At $t = 0s$, Albert is at $(9m, 1m, \sqrt{2}m)$. Albert moves at the rate of $(-2m, 0, 0)$ per second. So at $t = 1s$, Albert is at $(7m, 1m, \sqrt{2}m)$. Will Robert and Albert be able to see each other (i.e., both are visible) at some point? If so, how long can they see each other? (5 points)

4) Parametric Curves (10 Points)

Consider the two points $\mathbf{P_0}$ and $\mathbf{P_1}$. There exists another point **Q** that lies on the straight line connecting $\mathbf{P_0}$ and $\mathbf{P_1}$.

a) Write an equation to represent **Q** in terms of $\mathbf{P_0}$, $\mathbf{P_1}$ and a parameter **t**. (2 points)

b) In class, we discussed three ways to write the equations for parametric curves: as a linear interpolation between points, as a linear polynomial, and in matrix form. Give the equation for **Q** from part a) in all three ways. (3 points)

1. Linear interpolation:
2. Linear polynomial:
3. Matrix form:

c) What are the two values of **t** at which **Q** would equal $\mathbf{P_0}$ and $\mathbf{P_1}$? (2 points)

d) Calculate the tangent at **Q**. (2 points)

e) Does the tangent vary at every **Q(t)**? Why/why not? (1 point)

5) Bezier Curves (10 Points)

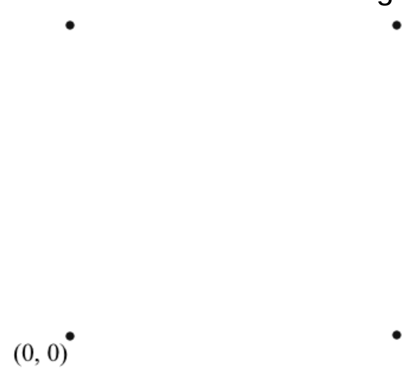
You are a fitting specialist at an upscale clothing store. But not just any clothing store, you work for Bezier Britches, a boutique shop known for selling the finest of bottoms to the busiest of Bezier business men. Your one and only job is to help busy Bezier business men find a pair of britches that best fits.

Sounds easy? In comes Bobby the Bezier Curve. Bobby needs a pair of britches, and fast. But he's so busy that he doesn't even know where his waist is! Before you can properly size him you'll need to find his waist.

Here is what he tells you. Fill in the blanks with the correct terms. (2 points):

- He's a ________ Bezier curve, which means he has 4 ___________ points and is a ________ degree (=order) polynomial.
- His waist is at t = 0.5.
- His ______________ points in order are: <0, 8>, <8, 8>, <8, 0>, <0, 0>

Given the above, you first make an estimate using De Casteljau's algorithm (2 points):



Estimate: (_____, _____)

Now you have a general idea of where his waist is, but you don't work at just any clothing store, you work at Bezier Britches. Here accuracy is top priority, so an estimate won't cut it. You'll have to solve for his waist directly. Looking at your fitter's manual, you find an equation that looks like it'll do the trick:

$$\dot{q} = \sum_{i=0}^{n}\left(\binom{n}{i}(t)^{i}(1-t)^{n-i} * \dot{p}_i\right) \qquad \binom{n}{i} = \frac{n!}{i!(n-i)!}$$

Using the equation above, and what you know about Bobby, solve for his waist. Show work. (5 points):

Your estimate and the actual position should be quite close, why? (1 point)

6) Joining Curves (10 Points)

Equations of two curves Q and R are given as follows:
$Q(t) = (1 + t^2)P_1 + (5t - 5t^2)P_2 + t^2P_3$.
$R(t) = (1 + t^2)P_3 + (5t - 5t^2)P_4 + t^2P_5$.
For both the curves $0 <= t <= 1$. P_n are the control points.

a) Are both curves C_0 continuous at Q(1) and R(0)? Explain. (5 points)

b) Are they both C_1 continuous at Q(1) and R(0)? Explain. (5 points)

7) Environment Mapping (10 Points)

a) What is the purpose of Environment Mapping? (2 points)

b) Which two types of geometries for environment maps did we discuss in class? Name one advantage for each of them that it has over the other. (4 points)

c) With environment mapping, is it easier to render metallic or diffuse objects? Explain why. (2 points)

d) Name two particularly computationally expensive operations that are part of the environment mapping algorithm, which can be done efficiently in a GLSL shader because special shader commands are available. (2 points)

8) Cubic Environment Maps (10 Points)

Given a cubic environment map and a light direction vector (**x**,**y**,**z**) on the surface of an object which uses this environment map for pure specular reflection (mirror-like), you need to figure out the color of the pixel to draw on the screen.

a) The light direction vector can be viewed as a ray intersecting the cubic environment map. How can you calculate which face the ray intersects? (3 points)

b) What are the coordinates of the intersection within that face? (3 points)

c) How do you get the (**u**,**v**) coordinates for the environment map texture associated with this face? (2 points)

d) Now we add another object to the scene, this time one with a diffuse surface. We still want to use **the same** cubic environment map for shading. What is the fundamental difference between the shading algorithm for the diffuse surface and that for specular surfaces? Explain your answer. (2 points)