Final Exam

CS 184: Foundations of Computer Graphics
Spring 2008
Prof. James O'Brien

Student Name: **Class Account Username:**

Instructions: ***Read them carefully!***

The exam begins at 12:40pm and ends at 3:30pm. You must turn your exam in when time is announced or risk not having it accepted.

Make sure you fill in your name and the above information, and that you sign below. Anonymous tests will not be graded.

***Write legibly**. If the person grading the test cannot read something, he/she will simply assume that you meant the illegible portion as a note to yourself and they will ignore it. If you lose points because part of your answer could not be read, you will not be given the opportunity to explain what it says.*

***Be clear and concise**. The answers to most questions should be short. If you find yourself writing an excessively long response, you may want to think more carefully about the question. Long rambling answers generally get fewer points that short ones do because there are more opportunities to mark something wrong.*

You may use two pages of notes while taking the exam. You may not ask questions of other students, look at another student's exam, use a textbook, use a phone or calculator, or seek any other form of assistance. In summary: do not cheat. Persons caught cheating will be subject to disciplinary action.

***Do not ask questions during the exam.** Most questions are unnecessary and they disturb other students. Figuring out what the exam question is asking is part of the test. If you think you have to make some unusual assumption to answer a problem, note what that assumption is on the test.*

I have read these instructions, I understand them, and I will follow them.

Your Signature: _____

Date: _____

Student ID: _____

Total Points: 133 + 10 *You Scored:* _____ + *Extra* _____

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1. Answer the following questions with True (T) or False (F) *1 point each*

_____ Cloth can be modeled reasonably well using a collection of particles attached by springs.

_____ Particle systems have become obsolete and are seldom used in modern applications.

_____ All types of numerical integration are basically the same and there is no strong reason to prefer one method over another.

_____ Active optical motion capture systems are make use of multiple cameras to determine the location of retroactive markers.

_____ Magnetic motion capture systems use trackers that return orientation and position information.

_____ The pseudo inverse of a matrix can be computed using the Singular Value Decomposition (SVD) algorithm.

_____ It is impossible to write a robust IK solver and as a result people typically use motion capture algorithms.

_____ Standard kinematic algorithms assume that articulated structures will have a ring topology.

_____ In 2D all IK problems have simple closed-form solutions.

_____ In 3D all IK problems have simple closed-form solutions.

_____ The Jacobian of a valid kinematic system will never be invertible.

_____ When representing directions in 3D using homogenized coordinates, the fourth coordinate (*i.e.* "w") will be zero.

_____ Overly large time-steps can cause a spring and mass simulation to go unstable.

_____ Motion capture data is often used in video games.

_____ Animations lacking motion blur may suffer from unnatural looking artifacts.

_____ The rendering equation discussed in class does not account for atmospheric scattering.

_____ The radiosity method operates from the assumption that all surfaces act like diffuse reflectors.

_____ Polished plastic surfaces typically have bright white specularities.

_____ Although photon mapping is an effective rendering technique, it is seldom used in practice because of its inability to model area lights.

_____ Ambient occlusion approximates global illumination by making diffuse shading proportional to the un-occluded area over a surface.

_____ Radiance is measured in units of power per second squared per cubic meter.

_____ Radiance falls off with distance.

_____ Catmull-Clark subdivision surfaces are a generalization of uniform, cubic tensor-product b-splines.

_____ Cubic NURBS curves will typically be C^2 across segment boundaries.

_____ Bézier surfaces can be converted to B-spline surfaces.

_____ Cubic B-splines have global support.

_____ A b-spline curve is always interpolates its control points.

_____ The parametric representation of a given geometric entity is unique.

_____ B-spline bases can be built for polynomials of degree other than cubic.

_____ In Catmull-Clark subdivision, the number of extraordinary points is proportional to the level of subdivision.

_____ The cones in the human eye have a flat spectral response function.

_____ Under linear perspective projection, straight lines always appear as straight lines.

_____ Under linear perspective projection, squares always appear as a square.

2. **Write the regular expression that concisely describes the light paths captured by the given rendering method.** (L = Light, D = Diffuse, S = Specular, E = Eye) *8 points*

   The real world _____

   Local illumination _____

   Basic raytracing _____

   Radiosity _____

3. **Imagine that you have a RGB monitor where the wires have been swapped so that the red, green, and blue outputs from the computer have been respectively attached to the green, blue, and red inputs on the monitor. When one attempts to display the following colors, what colors will actually appear on the screen?** *8 points*

   Red _____

   Green _____

   Blue _____

   Cyan _____

   Magenta _____

   Yellow _____

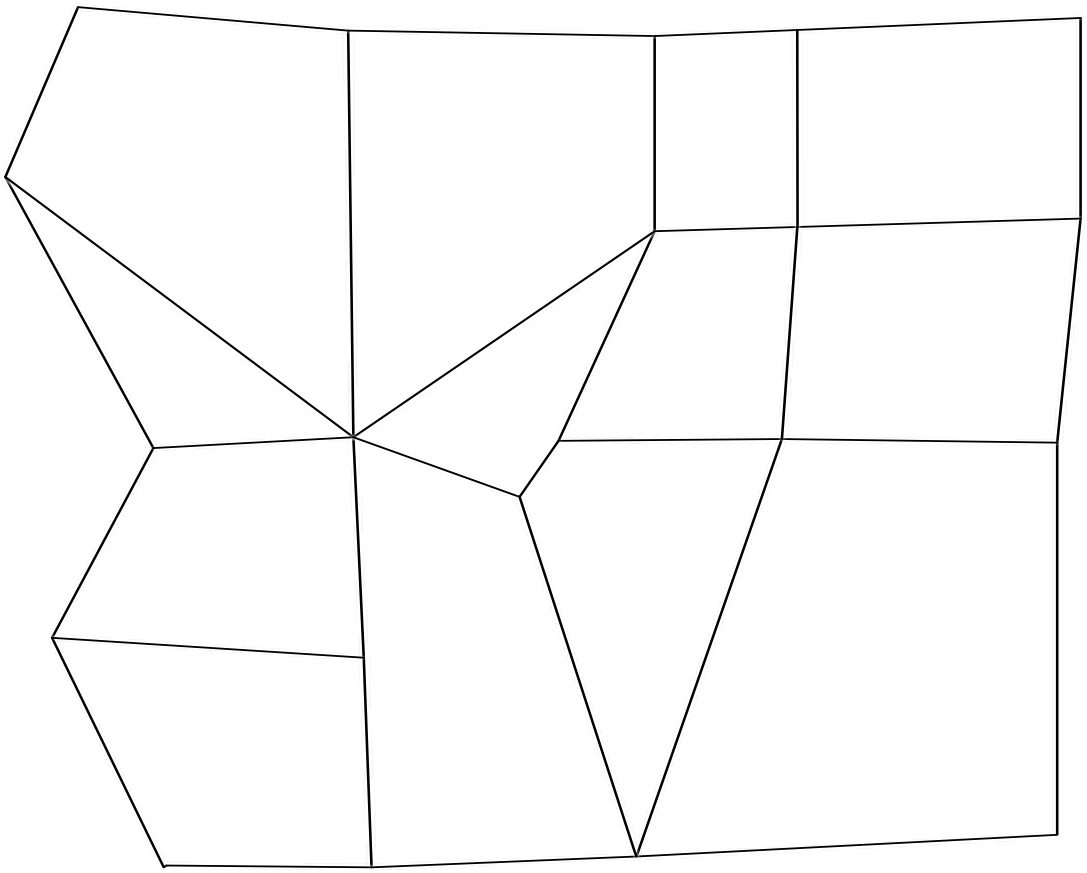
   Black _____

   White _____

4. **If a surface is defined implicitly by the function $f(\mathbf{x}) = 0$, write out the equation you would use to compute the surface's normal at some point.** (Assume that negative values are inside the surface.) *4 points*

5. **If a surface is defined explicitly by the function $\mathbf{x} = f(u, v)$, write out the equation you would use to compute the surface's normal at some point.** *4 points*

6. Here is a piece of mesh. Draw the result of applying one iteration of Catmull-Clark subdivision. Then circle all vertices (both original and the new ones you added) that are extraordinary. *Note: I am only interested in the topology of your answer.* *7 points*



7. Name a phenomenon that can be modeled easily using radiosity but that cannot be modeled with a basic ray-tracing algorithm. Give an example. *3 points*

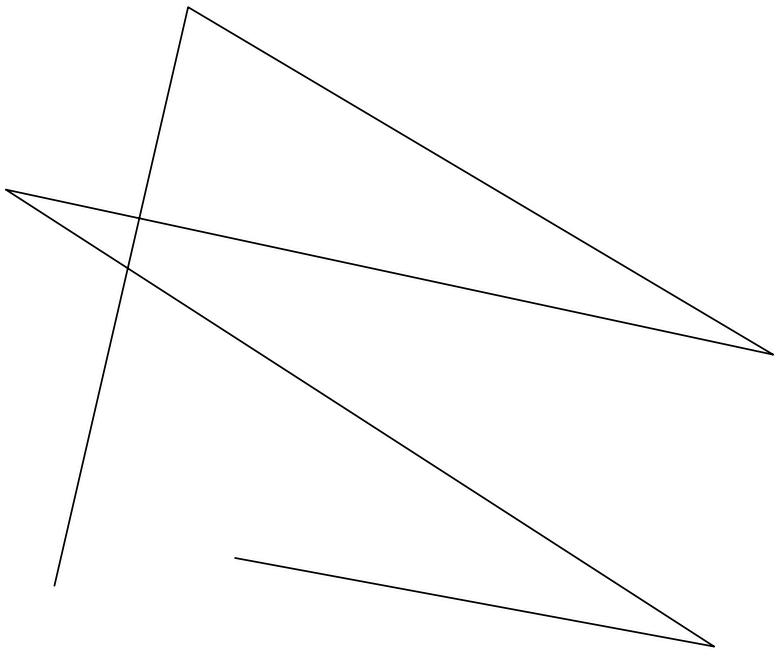
8. Below are two 4x4 homogenized transformation matrices. What does the first one do? How does the effect produced by the second one differ from that produced by the first? *4 points*

$$\begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

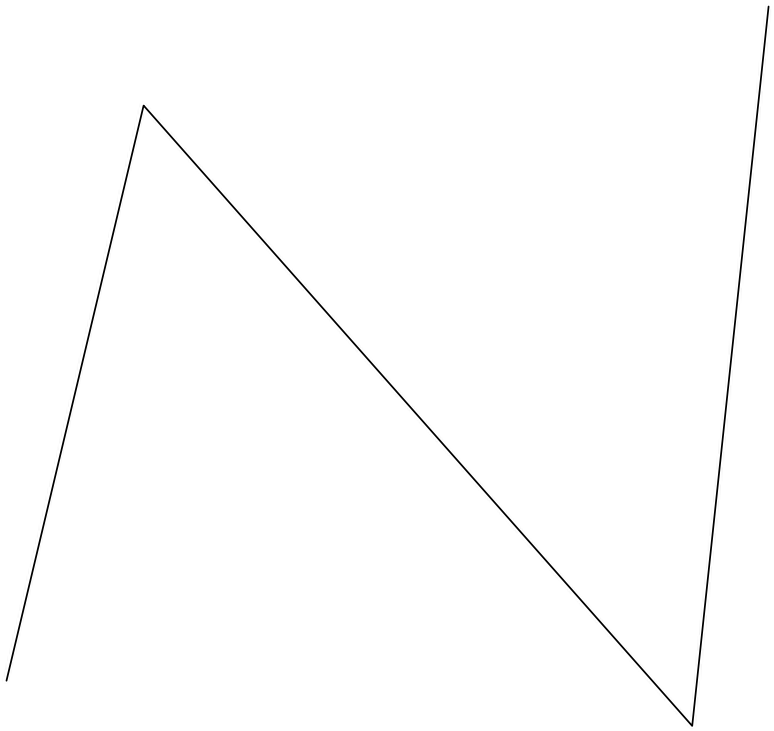
The first one will: _____

The second one will: _____

9. Draw the convex hull of the shape shown below. *2 points*

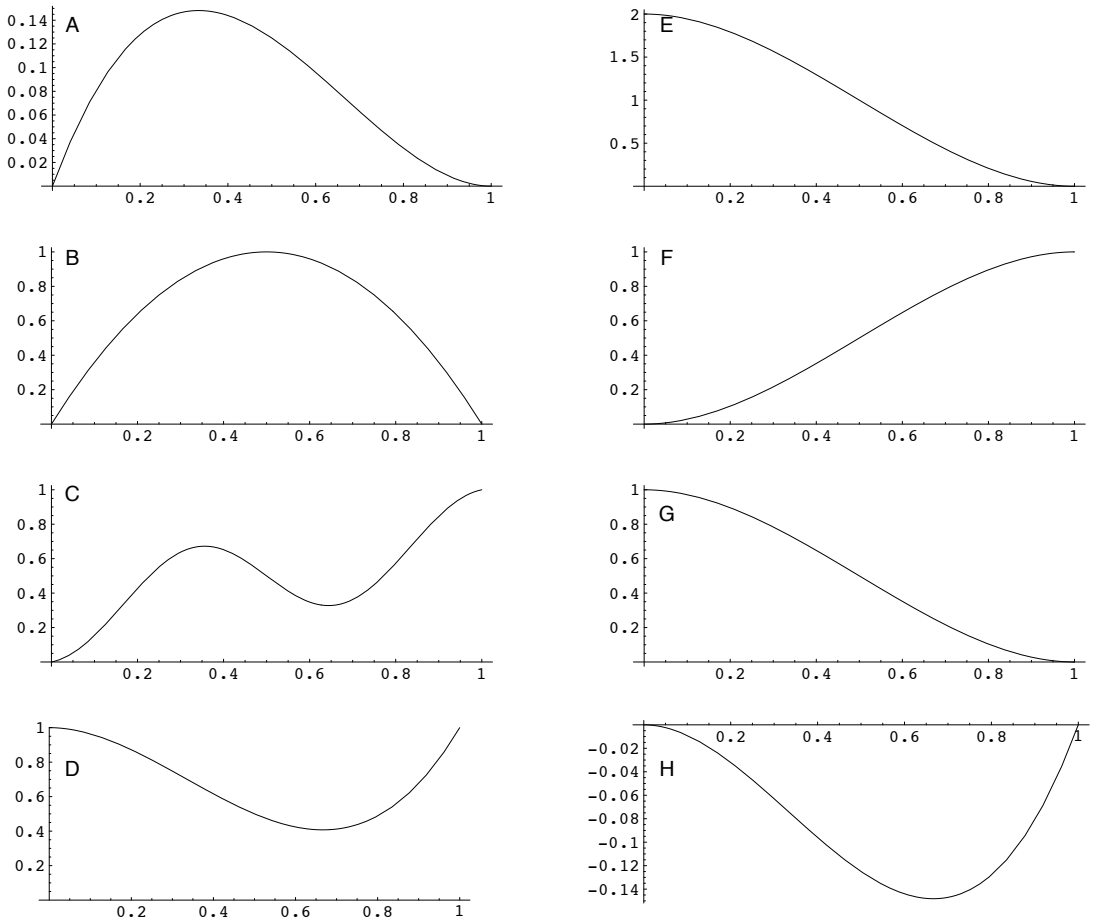


10. The diagram below is the control polygon for a Bezier curve segment. Draw the curve and show how de Casteljau's algorithm can be used to subdivide the curve into two halves. *Make sure your drawing is geometrically reasonable and shows correct curve tangents for the the beginning, middle, and end of each segment.* *5 points*



11. Given a 3x3 matrix that encodes a 3D transformation, how does *singular value* decomposition separate the matrix into scale and rotation components? *4 points*

12. There are 8 functions plotted below. Neatly cross out the ones that are not part of the cubic Hermite basis set. Next to the remaining plots write what feature of the curve that basis controls. *6 points*



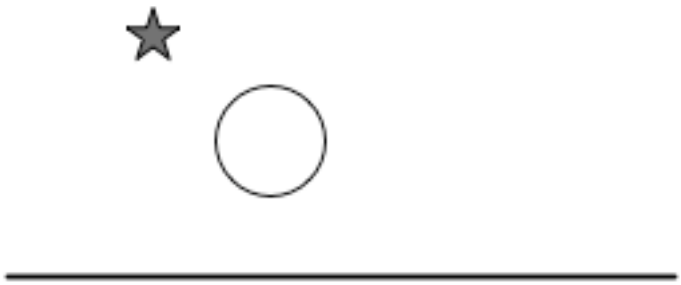
For those that are NOT Hermite basis functions write a single short sentence that explains why they could not be. Your reason should be simple. ***Note: "It isn't what I have in my notes," "it won't fit," "it doesn't solve the equations," or other generic answers will not be accepted.*** *4 points*

Letter	Reason
_____	_____
_____	_____
_____	_____
_____	_____

13. You are working on the shader for computer rendering of a glass of milk that is supposed to look as realistic as possible. Unfortunately, the results look more like a glass of white paint than like a glass of milk. What is likely the problem with your milk shader? *3 points*

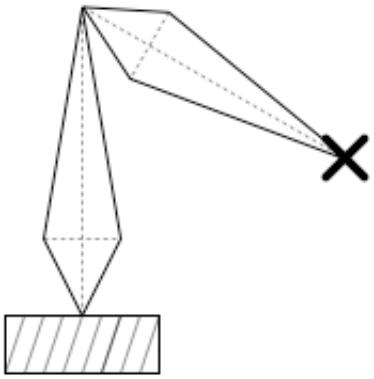
14. When rendering a scene with a *photon-mapping* method, what part of the solution must be recomputed when light source moves? *3 points*

15. In the diagram below of a light source, a clear glass ball, and a diffuse surface, draw lines illustrating the path traveled by light to form a refraction caustic on the surface. *3 points*



16. When computing the boolean union of two arbitrarily oriented triangles (in 2D), what is the minimum and maximum number of sides that a resulting polygon could have? Draw an example of the minimum and maximum shapes. *3 points*

17. In the context of doing inverse kinematics, draw an example configuration for a two-link arm that results in a singular Jacobian. Your example arm should have links that are connected by a rotation joint and whose root link is attached to ground with a rotation joint. Make sure your diagram is clear. Use an X to indicate the goal point. *3 points*



Example figure

18. Suppose you have a color C = (c,m,y) in the CMY subtractive color space. How would you express this color in the RGB additive color space? *4 points*

r =

g =

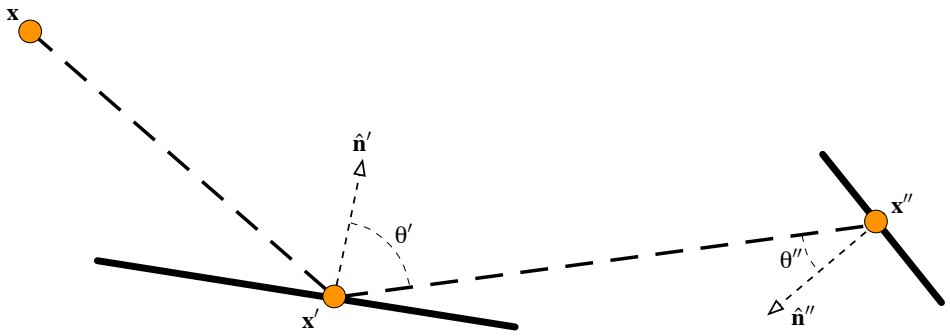
b =

19. Write out a parametric equation for a sphere. *4 points*

20. Write out an implicit equation for a line in 3D. *3 points*

21. Consider the following equation and diagram:

$$L_s(\mathbf{x},\mathbf{x}') = \delta(\mathbf{x},\mathbf{x}')\left[E(\mathbf{x},\mathbf{x}') + \int_S \rho_{x'}(\mathbf{x},\mathbf{x}'')L_s(\mathbf{x}',\mathbf{x}'')\frac{\cos(\theta')\cos(\theta'')}{||\mathbf{x}'-\mathbf{x}''||^2}d\mathbf{x}''\right]$$



Explain what effects each of the following is responsible for. *15 points*

$\delta(\mathbf{x},\mathbf{x}')$ _____

$E(\mathbf{x},\mathbf{x}')$ _____

$||\mathbf{x}'-\mathbf{x}''||^2$ _____

$\cos(\theta')$ _____

$\rho_{x'}(\mathbf{x},\mathbf{x}'')$ _____

EXTRA CREDIT *10 points*

Given two planes in R3 described by the implicit equations:

Plane 1: $\mathbf{n}_1 \cdot \mathbf{x} - f_1 = 0$

Plane 2: $\mathbf{n}_2 \cdot \mathbf{x} - f_2 = 0$

one can generally write the parametric equation for their line of intersection as:

Line of intersection: $\mathbf{x} = \mathbf{a} + t\mathbf{d}$

Write out equations for computing both $\mathbf{a}$ and $\mathbf{d}$. Note any situations where your equations would not have a solution.

Your answer must be neat and clear. No points will be awarded for imprecise answers that do not fit in the boxes. Do not attempt this question until you have completed the rest of the exam!

$\mathbf{d} =$ *3 points*

$\mathbf{a} =$ *6 points*

Fails when: *1 point*