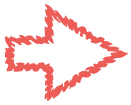
Final Exam

CS 184: Foundations of Computer Graphics
Spring 2015
Prof. James O'Brien



Student Name: **Class Account Username:**

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

*This exam begins at **7:10 pm** and ends at **9:00 pm**. 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: _____

1. Please fill in each of the blanks with an appropriate answer. *2 points each blank*

The Euler integration scheme tends to cause simulations to "blow up." The implicit version of this scheme, known as _____, is much more stable but has a tendency to damp motions artificially.

The inverse kinematics algorithm we discussed in class involve numerical root finding for a set of nonlinear equations and can be solved using a variation of _____ method.

_____ motion capture systems record the position of reflective markers on the subject.

The cross-product of the tangent vectors of an parametric surface generally can be used to compute the surface _____.

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

Temporal anti-aliasing is often called _____.

The radiosity method builds on the assumption that all surfaces in a scene are _____ reflectors.

The final gather often is the most time consuming step of the rendering method known as _____.

Computing the form factors between surface patches often is the most time consuming step of the _____ rendering method.

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

Catmull-Clack subdivision surfaces are a generalization of uniform, cubic, tensor-product _____ to irregular meshes.

NURBS surfaces are a generalization of uniform, polynomial, tensor-product _____ to be non-uniform and rational-polynomial.

In Catmull-Clark subdivision, the number of extraordinary points _____ during the third round of subdivision.

Under linear perspective projection, straight lines always appear as _____ in the resulting images.

Violet spectral colors appear at the _____ end of the visible spectrum.

The _____ of an orthonormal matrix is equal to its transpose.

The _____ parameterization of 3D rotations uses a hypersphere in 4-dimensional space.

The "P" in BSP-Tree stands for _____.

_____ is a special case of a simple point light source where the viewer is infinitely far away.

_____ is used to change the surface normal vectors when shading an object so that it appears to have surface bumps and other geometric details.

When two curve segments join at a point and both curves approach that point with tangent vectors of equal direction and magnitude, the joining is said to be _____ continuous.

When two curve segments join at a point and both curves approach that point with non-zero parallel tangent vectors from opposite directions, the joining is said to be _____ continuous.

Steradians are the dimensionless units used to measure _____.

When the viewpoint used to generate a ray-traced image changes, updating the solution for the new viewpoint requires recomputing _____.

2. Answer the following questions with True (T) or False (F) *2 points each*

_____ Cloth can be modeled in a perfectly realistic way using a collection of particles attached by springs.

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

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

_____ Radiance grows with the square of distance along a straight line in free space.

_____ Both the cones and rods in the human eye have constant spectral response functions.

_____ Under perspective projection, all sets of parallel lines will remain parallel in the image.

_____ Any set of non-intersecting polygons can be sorted in front-to-back order from any perspective.

_____ Shining an ultraviolet light on scorpions can create a situation where ultraviolet photons are adsorbed and lower energy photons are then emitted in the visible part of the spectrum.

_____ The force exerted by a spring with non-zero rest length is given by a function that is linear in terms of the endpoint locations.

_____ A light field records the light passing through a single point in space in all directions.

_____ In a kinematic skeleton, every body must have exactly one outboard joint.

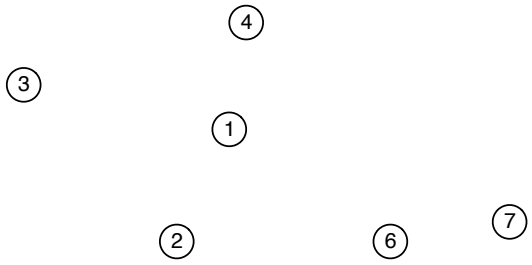
_____ Apple retina displays have a dynamic range exactly equal to that of the human eye.

_____ A rotation matrix always has determinant of -1.

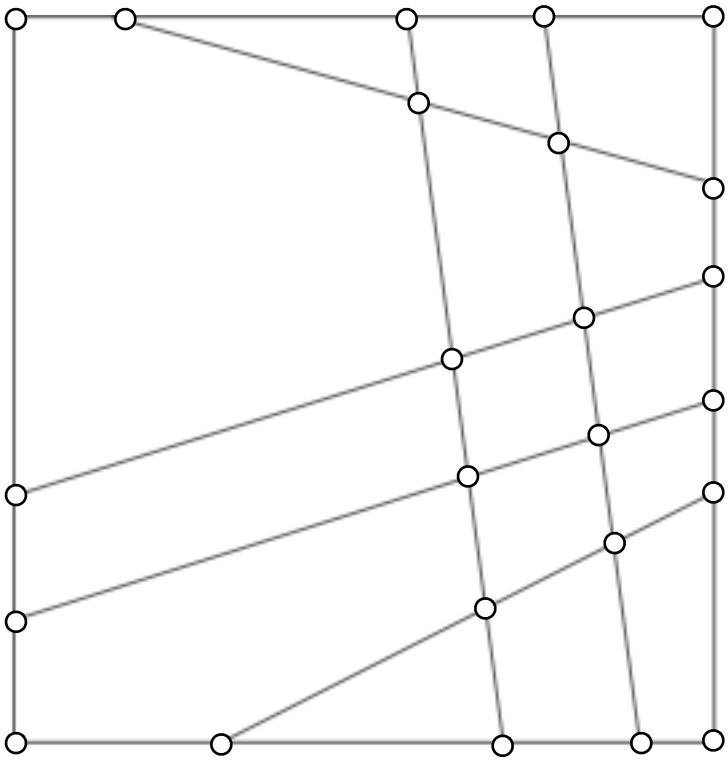
_____ Motion capture systems typically run at rates between 20 and 30 samples per second.

_____ The sky is blue because photons in the red-orange parts of the spectrum are absorbed by nitrogen atoms.

3. The diagram below shows control points for a curve made by joining two cubic Bezier segments. However control point #5 has been removed. Indicate location(s) where #5 may be placed to achieve C1 continuity and where it may be placed to achieve G1 continuity. Clearly label your diagram. *6 points*



4. 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. The square boundary lines are part of the mesh.*** *8 points*



5. Below are three 4x4 homogenized transformation matrices. Describe what they will do. *6 points*

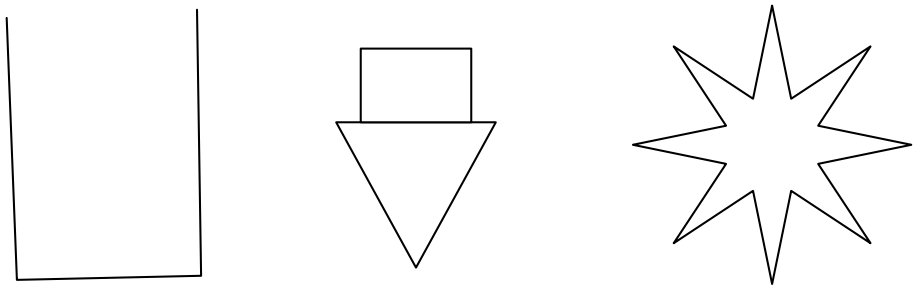
$$\begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 6 \end{bmatrix} \quad \begin{bmatrix} 6 & 0 & 0 & 0 \\ 0 & 6 & 0 & 0 \\ 0 & 0 & 6 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The first one will: _____

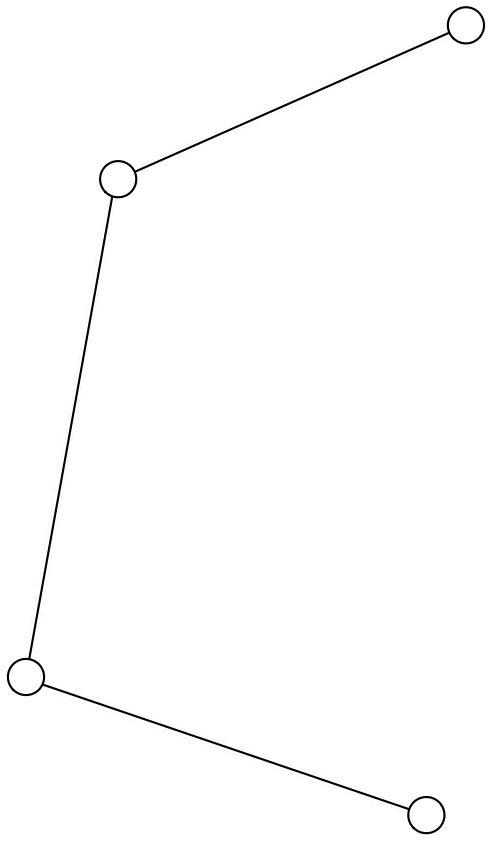
The second one will: _____

The third one will: _____

6. Draw the convex hulls of the <u>each</u> of the shapes shown below. *6 points*



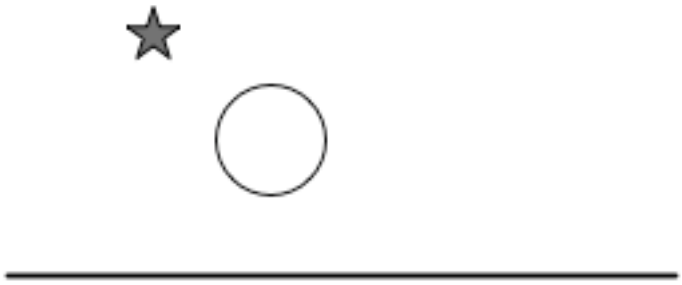
7. The diagram below is the control polygon for a Bezier curve segment. Draw the curve and show how de Casteljau's algorithm can be used to subdivide the curve into two halves. *Make sure your drawing is geometrically reasonable and shows correct curve tangents for the the beginning, middle, and end of each segment.* *6 points*



8. Given a rotation matrix, how would you determine the axis that it rotates around?

3 points

9. 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*

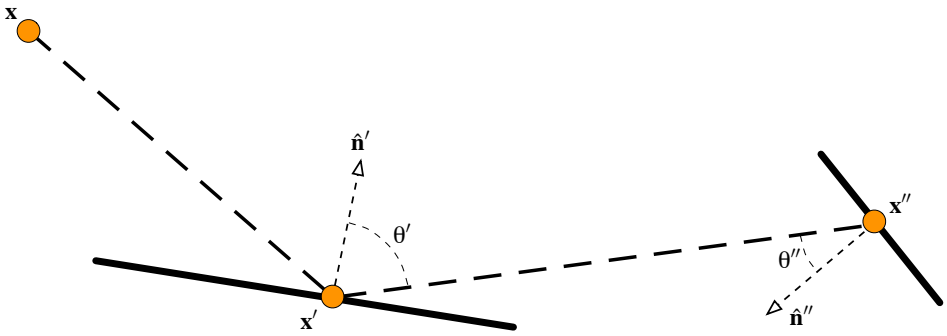


10. Write out an explicit equation for a sphere. Be sure to specify the range of your parametric variables to exactly cover the sphere once. *4 points*

11. Given three points, A, B, and C, write out an implicit equation for the plane in 3D that contains all three points. You may assume the points are distinct and not co-linear. *4 points*

12. 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. *10 points*

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

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

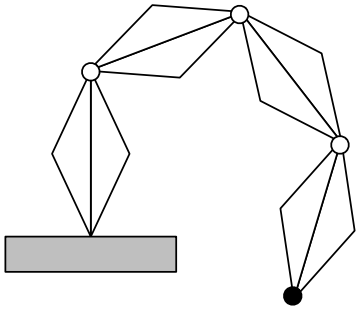
$||\mathbf{x}'-\mathbf{x}''||^2$ _____

$\cos(\theta')$ _____

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

13. 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*

14. Consider this diagram showing a four-joint arm in 2D where each joint is a simple pin joint and the base is fixed in space.

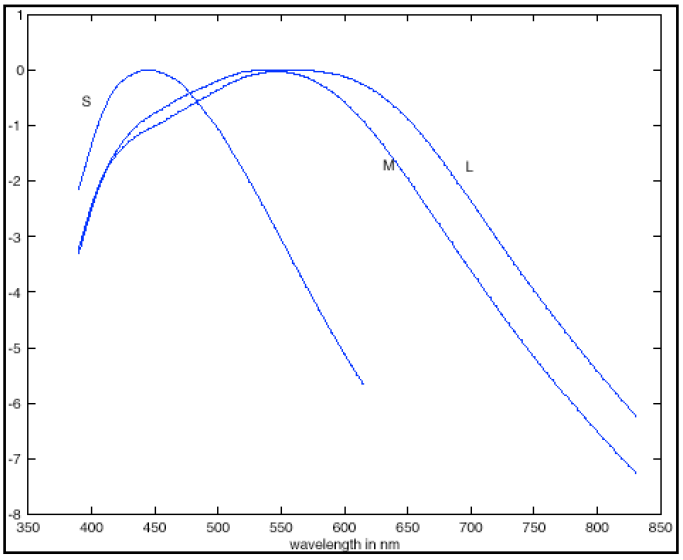


If we are solving an IK problem to place the tip of the arm (the black dot) at a particular location, what is the size of the Jacobian matrix we will be working with? *3 points*

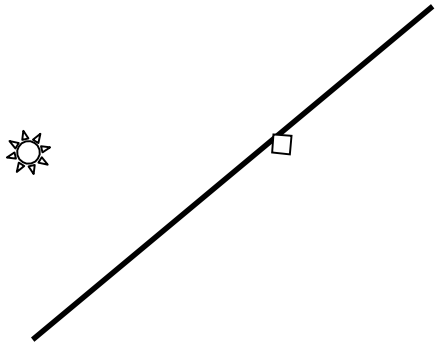
Draw any one configuration of the arm where two columns of the Jacobian will be parallel vectors. *5 points*

15. Name two types of useful image effects that would require shooting more than one ray per pixel in a ray-tracer. *4 points*

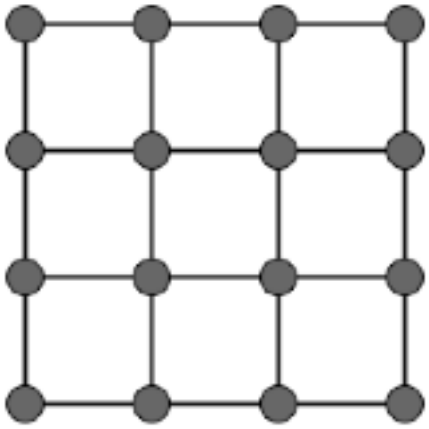
16. The following are the response curves for the cones in the human eye. Which type of cone is most sensitive to red light? *2 point*



17. Consider the diagram below. A location has been marked on the surface. Indicate a viewer position such that a viewer looking at the surface from that position would see a specular highlight on the surface at the location marked with a small square/diamond. *3 points*



18. On the diagram below, draw the springs that should be added to provide some resistance to shearing. *4 points*



EXTRA CREDIT *+5 points*

Given a plane and a sphere:

Plane: $\hat{\mathbf{n}} \cdot \mathbf{x} + f = 0$

Sphere: $||\mathbf{c} - \mathbf{x}|| - r = 0$

Write out a simple mathematical expression that will give the point on the sphere which is furthest away from the plane. (You may *not* include conditional statements.)

When is this point not unique?

When the point is not unique, what will your expression produce?

Your answers must be neat and clear. No points will be awarded for imprecise answers. Your answers should be in the form a simple mathematical expressions that you have drawn a box around. Do not attempt this question until you have completed the rest of the exam! There will be no partial credit for this question. Use the below space and back of the page to work out your answers, and do not clutter up the above space with anything other than your final answers.