Instructions: Read them carefully!

The exam begins at 2:40pm and ends at 4:00pm. You must turn your exam in when time is announced or risk not having it accepted.

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

Write legibly. If the person grading the test cannot read something, s/he 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 one page 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: 241 + 10 You Scored: ________________ + ________________
1. Please fill in each of the blanks with an appropriate answer.  
   2 points each blank, 84 Total

   True or False: The dynamic range of intensities that can be displayed with the projector in 306 Soda is smaller than that what can be perceived by the human eye. ___________________

   True or False: Humans are good at judging the relative brightness of two squares on a screen when there is a black band separating them. ___________________

   Visible light falls roughly in the range of __________________ nanometers at the VIOLET end of the spectrum to __________________ nanometers at the RED end.

   Fill in the three missing colors in order: Red, Orange, __________________, Green, __________________, Indigo, __________________.

   True or False: The light we see reflected off most objects consist of a single wavelength (or very narrow band of wavelengths) of light. __________________

   The sensitivity curves for the __________________ and __________________ cones have a the least amount of overlap.

   The outer part of the retina contains very few __________________

   The term AABB stand for ________________________________

   True or False: Any color humans can see can be reproduced using any three distinctly colored light sources. __________________

   __________________ are distinct materials that appear to be the same color under some specific lighting.

   __________________ is the main phenomenon that makes the sky appear blue.

   The __________________ is a function describes how much light coming in from one incoming direction goes out in another outgoing direction.
True of False: Spencer's law describes how refractive materials behave.

True of False: The exponent in the Phong shading model controls how shiny a material appears.

A ______________________ can be thought of as a camera located “at infinity”.

True or False: Stochastic sampling tends to over-emphasize edges so that shading may appear discontinuous.

True or False: Flat shading is named after the French computer graphics researcher Jon-Paul Flat.

True or False: Rotation is a nonlinear transformation.

The determinant of an arbitrary rotation matrix is always ____________________.

True or False: Matrix multiplication is commutative.

True or False: Homogenized coordinates are needed to allow perspective to be expressed as matrix multiplication.

Of the various methods discussed in class for representing rotations, the method of ____________________ is least appropriate for interpolation due to singularities which include gimbal lock.

True or False: Marching cubes is a method for building polygonal surfaces.

The implicit formula for a sphere is ____________________.

True or False: BSP Trees can be used to accelerate ray intersection tests for complex scenes.
Under *perspective* projection a set of parallel lines will ________________ unless the lines are parallel to the image plane.

Under *orthographic* projection spheres will generally appear as ________________.

Which points in a linear perspective image are vanishing points for some set of parallel lines? ________________

A key feature of Bresenham's line drawing algorithm is that it uses *only* ________________ arithmetic.

The ________________ breaks a matrix $A$ into $A = (U \ S \ Transpose(V))$ where $U$ and $V$ are orthonormal and $S$ is diagonal.

True or False: A BSP tree can be used to quickly sort polygons in front-to-back order. __________

True or False: The peacock feathers results from wave interference. ________________

True or False: Rotation about an arbitrary axis in 3D requires three separate transformation matrices. ________________

True or False: Systems like OpenGL typically convert everything to triangles before rendering. ________________

True or False: BSP Trees will always be balanced. ________________

True or False: The marching cubes algorithm generated a quad mesh. ________________

Finding the interaction of a ray with a sphere requires solving a ________________ equation.

True or False: BSP Trees will always be balanced. ________________
2. If you have two orthogonal unit vectors, A and B, then we can write the dot and cross products as $A \cdot B$ and $A \times B$, respectively. Simplify the following expressions: 8 points

\[
\begin{align*}
A \cdot (B \times A) &= \\
(B \times A) + (A \times B) &= \\
B \times (A \times B) &= \\
B \times (B \times (B \times A)) &=
\end{align*}
\]

3. You have a sphere centered at $[0,0,4]$ with radius 5, and a ray from $[10,0,0]$ in the direction $[-1,0,0]$. Write the implicit equation for the sphere, the parametric equation for the ray, and compute the coordinates of the intersection point[s]. Be neat and clear! 15 points

Sphere equation:

Ray equation:

Intersection[s] at =

4. Write out a 3x3 transformation matrix that will rotate -45 degrees about the Y axis. 6 points

5. Circle the types of transformations that to be expressed in matrix form do NOT require homogenized coordinates. 2 points

Translation
Rotation
Shear
Scale
Perspective
6. Draw the single *convex hull* that encloses all four shapes shown: 6 points

7. Draw the single *axis-aligned bounding box* that encloses all four shapes shown: 6 points
8. One of the diagrams below shows a cube under orthographic projection, the other under perspective projection. Label which is which.  

2 points

9. Given a rotation encoded as an exponential map with the vector shown, write out a vector that express the inverse rotation. (units are degrees)  

3 points

[10, 20, 0]

10. Given a rotation encoded as a quaternion, in general how is the rotation changed when the only the real part is negated?  

3 points

11. Write down plausible RGB values for the following materials:  

6 points

Glossy Metallic Red  
\( Kd = \)  
\( Ks = \)

Glossy Plastic Yellow  
\( Kd = \)  
\( Ks = \)

Flat Blue  
\( Kd = \)  
\( Ks = \)
12. If shading a point at the origin with normal \([0,0,1]\) and \(K_d=[0.1,0.2,0.3]\), where the light is located at \([0,4,3]\) with intensity 5 (white), and the eye located at \([27,91,17]\), compute the RGB value of the diffuse lighting term.  

10 points

13. Circle the 3D homogenized matrix that would do nothing.  

4 points

\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 \\
\end{bmatrix}
\quad \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 2 \\
\end{bmatrix}
\quad \begin{bmatrix}
2 & 0 & 0 & 0 \\
0 & 2 & 0 & 0 \\
0 & 0 & 2 & 0 \\
0 & 0 & 0 & 2 \\
\end{bmatrix}
\quad \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1/2 \\
\end{bmatrix}
\]

14. When solving for the intersection of a ray with a plane, as discussed in class, write out the conditions on beta, gamma, and t that would indicate that there is an intersection.  

12 points

What condition should you test for that would indicate that there is no solution for beta, gamma, or t?  

4 points
15. The following line segments will be inserted into a BSP Tree in the order indicated. As discussed in class, the lines themselves will be used to define the split planes. The numbers are on the positive side of each line. The negative-side children should be on the left of your tree and the positive-side on the right.

Diagram the resulting tree below. If needed, show where line segments need to be split by marking on the above figure. Also, indicate the names of the split parts by writing labels on the figure above. (For example, if there were a segment 11 and it was to be split, you would draw a mark showing where it would be split and label the resulting pieces 11a and 11b.) 13 points

List the back-to-front traversal order that would result for the location indicated by the viewer icon (the star). 9 points
16. Write out the 3x3 matrix for a rotation about the X axis. Now write out a 3x3 matrix for a rotation about the X axis that would result if we did rotations *clockwise* instead of *counterclockwise*.

4 points

17. 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 blue, red, and green inputs on the monitor. When one attempts to display the following colors, what colors will actually appear on the screen?

Cyan ____________________________________
Magenta __________________________________
Yellow ____________________________________
Red ______________________________________
Green ____________________________________
Blue _____________________________________
Black ____________________________________
White ____________________________________
18. On the figure below write the appropriate letter in each of the blanks to label the diagram properly. Some of the letters are just there to confuse you.  

16 points

A Center of projection  
B Scale factor  
C Distance to image plane  
D Projection singularity distance  
E Top clipping plane distance  
F Magnetic zero  
G Near clipping plane distance  
H Look-at direction  
I Bottom clipping plane distance  
J Focal distance  
K Right clipping plane distance  
L View up vector  
M View plane normal  
N Far clipping plane distance  
O Aperture  
P Origin
19. Write out a series of 4x4 matrices that would scale an object by 2x along the axis [1,1,0] with the point [0,3,4] staying fixed in space.

Note that unclear or sloppy answers will not receive any credit.
Given:

A ellipse defined by

\[
\left( \frac{x - c_x}{r_x} \right)^2 + \left( \frac{y - c_y}{r_y} \right)^2 + \left( \frac{z - c_z}{r_z} \right)^2 - 1 = 0
\]

and a ray defined by

\[
\text{ray}(t) = [p_x, p_y, p_z] + t [d_x, d_y, d_z]
\]

Write out the quadratic equation that should be solved to find the intersection.

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