Be sure to write your CS login on every page! There are 7 pages in the exam – make sure you have all of them! Please read the instructions carefully.

The exam is closed book and closed notes. You will have the entire exam period for the exam, but the exam is designed to be completed in less time.

You may use a calculator, however, the exam is designed such that you should not need one. If you feel like you want to use a calculator, there is probably an easier way to do what you're trying to do.

If you need additional space, use the back of the page. Please make a note telling us to look there.

Some notes:
Drawings are not to scale unless explicitly denoted that way. Your drawings do not need to be to scale, but be sure to label important measurements.

We would prefer if you did not simplify numbers: leave fractions and radicals. We would much rather see ¼ than .25, or $\sqrt{2}$ rather than 1.414…

Vectors are denoted by lowercase bold letters (**a**, **b**, **x**), while matrices are denoted by uppercase bold letters (**A**, **B**, **M**).

Assume that we do everything with a post-multiply convention (as we did in all of the examples in class). That is, if we are transforming a point **x** by matrix **M**, we write **Mx**.

Always assume a right-handed coordinate system. The Y-axis points upwards.

Some useful facts to remember:

For 3 dimensional vectors…

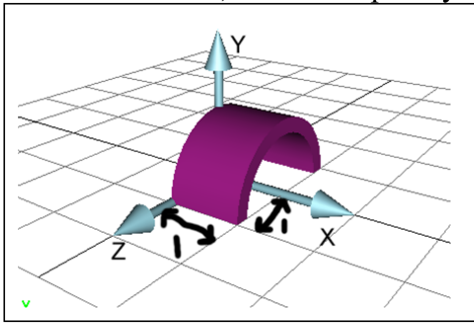
Vector dot product: $a \bullet b = (a_x b_x + a_y b_y + a_z b_z)$

Vector cross product: $a \times b = (a_y b_z - a_z b_y, a_z b_x - a_x b_z, a_x b_y - a_y b_x)$

Q1 __ / 10	mean: 4.33	Overall Mean: 58.11	
Q2 __ / 12	mean: 7.17	Overall Median: 58	
Q3 __ / 20	mean: 11		
Q4 __ / 8	mean: 6.84	A >= 69	(10 students got this)
Q5 __ / 8	mean: 3	AB >= 64	(8 students got this)
Q6 __ / 8	mean: 6.84	B >= 52 (12 students)	
Q7 __ / 9	mean: 3.73	BC >= 48	
Q8 __ / 10	mean: 5.77	C >= 46	
Q9 __ / 15	mean: 9.77	D >= 30	

Question 1: Make A Matrix (10 pts)

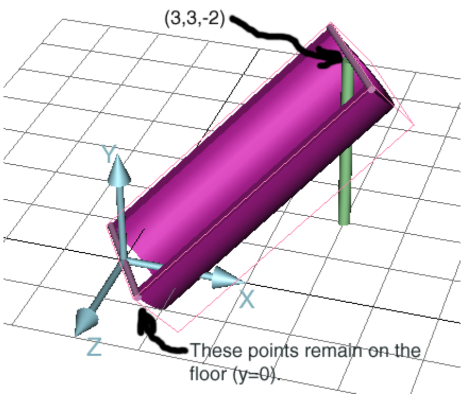
You are given an object that is a unit "half pipe" (that is, it's a cylinder that has unit length and radius, but no ends, and chopped in half lengthwise). The half-cylinder points down the x axis, and it completely above the XZ plane as shown in this picture:

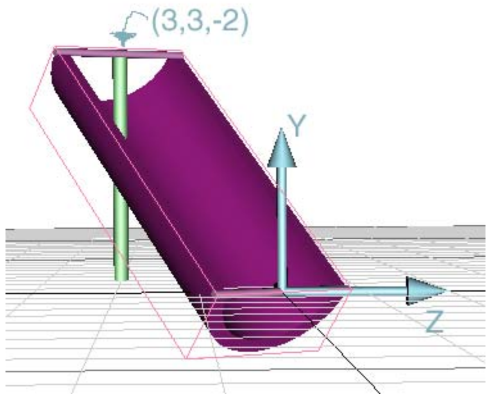


Hints:

1. Read the notes on the first page of the exam!
2. If you want to figure out the angles, you're doing this the hard way. It's too hard to do it this way by hand.
3. The easiest way to solve this problem does not require multiplying matrices.
4. Normalize vectors last.

You are writing a snowboarding simulation that requires creating a half-pipe than goes down hill. The top center of the half pipe should be at (3,3,-2), while the bottom center should remain at the origin. The corners of the half pipe that are closest to the origin should remain on the ground (y=0). The half pipe should still have radius 1,and should be below its center, as shown in these pictures:





Provide a matrix that transforms the initial half-pipe to the final configuration.

Trick → look at where Vectors go!

$x \rightarrow 3, 3, -2$

$z \rightarrow$ y component is zero

$(3, 3, -2) \times (0,1,0) = (2, 0, 3)$ (-2,0,-3) is o.

$y \rightarrow$ perpindicular to x and z, point downward

$(3, 3, -2) \times (2, 0, 3) = (9, -4-9, 0-(6)) = (9, -13, -6)$

9^2+13^2+6^2=286

normalize z and y

$$\begin{bmatrix} 3 & 3 & -2 & 0 \\ 9/\sqrt{142} & -13/\sqrt{142} & -6/\sqrt{142} & 0 \\ 2/\sqrt{13} & 0 & 3/\sqrt{13} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{matrix} 3 & 3 & -2 \\ 9/\sqrt{286} & -13/\sqrt{286} & -6/\sqrt{286} \\ 2/\sqrt{13} & 0 & 3/\sqrt{13} \\ 0 & 0 & 0 \end{matrix}$$

- Lots of partial credit given
- Transposes accepted

Question 2: Renderers and Rendering (12 pts)

2.A Describe an effect that a ray tracing renderer can produce that a (traditional) radiosity renderer could not

Any of the following are OK:
- specular highlights
- reflection
- refraction
- hard edged shadows (not really correct, but accepted)

2.B Describe an effect that a radiosity renderer can produce that a ray tracer could not.

Any of the following are OK:
- global illumination
- indirect lighting off of diffuse objects
- color spill from diffuse objects
- soft shadows from area light sources (not really correct, but accepted)

2.C Describe an effect that a bi-directional ray tracer could produce that a traditional ray-tracer could not.

Some specular object's reflection illuminating a diffuse object (e.g. bathroom mirror lighting your face)

Question 3: Which Algorithm? (20 pts)

Which of the following algorithms could have been used to produce the following results?

1. Floyd Steinberg Dithering
2. Phong Shading
3. Phong Lighting
4. Gouraud Shading
5. High-Dynamic Range Image as Environment Map
6. Lightfields
7. Forward-map image warping
8. Reverse map image warping
9. Loop subdivision surfaces
10. Catmull-Clark subdivision surfaces
11. Cubic B-Spline patches
12. Butterfly Algorithm
13. Quicktime VR (Chen's original 1995 version, discussed in class)
14. Ordered Dithering
15. Z – Buffering
16. BSP Trees

For each result, list the numbers of the algorithms that might have been used. List all the correct answers (there may be more than one, or there may be none if none of the ones listed above can do the trick!)

3.A The color of a vertex is computed to have a bright white specular highlight.

3, 5

3.B A mesh of points is interpolated by a smooth surface.

12

3.C A black and white photograph is converted to print on a black and white laser printer.

1,14

3.D. When 3.C was done, smooth gradations of gray appear as blocks of constant levels.

14

3.E Lighting is computed that has global illumination effects.

None (5 is not counted as wrong)

3.F Standard OpenGL lighting and smooth shading is used on a polygonal object.

3,4 (15 is not counted as wrong)

3.G Photographs of an object are resampled allowing the user to view the object from any point within a region.

6 (quicktime VR is wrong since it locks your head in place)

3.H An image was stretched, but the resulting image has gaps.

7 (the reserve mapping algorithm does not produce gaps)

3.I A quadrilateral mesh is used to define a smooth surface, without turning it into triangles.

10,11

Question 4: Z-Buffering (8 pts)

One major benefit of the Z-Buffer algorithm is that it does not require the objects that are drawn to be drawn in any particular order.

Give TWO examples of cases where the order that things are drawn do matter for Z-Buffering.

Any two of:

- two objects have equal Z-values
- two objects have very close z-values (z-fighting)
- transparent objects
- objects are edge anti-aliased

Question 5: Matrix Transforms (8 pts)

A vertex is drawn at the origin. It is viewed through a camera that has its viewing matrix:

$$\begin{bmatrix} \frac{1}{2} & -\frac{1}{2} & 0 & -2 \\ \frac{1}{2} & \frac{1}{2} & 0 & -2 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The modeling transformation that is applied to the point is:

$$\begin{bmatrix} 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & 4 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

If this matrix is used for the perspective projection:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

Where does the point appear on the "film" plane? (the x,y position)

$$p = PCM \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

$$= PC \begin{matrix} 2 \\ 4 \\ 6 \\ 1 \end{matrix} = P \begin{matrix} 1 - 2 - 2 = -3 \\ 1 \;\; 2 - 2 = 1 \\ 6 + 2 = 8 \\ 1 \end{matrix}$$

$$P \begin{matrix} -3 \\ 1 \\ 8 \\ 1 \end{matrix} = \begin{matrix} -3 \\ 1 \\ 1 \\ -8 \end{matrix} = \text{Divide by W} \quad \left(\frac{3}{8}, \frac{-1}{8} \right)$$

Question 6: Mapping Techniques (8 pts)

What is the difference between Bump Mapping and Displacement Mapping?

Bump mapping only changes the normal, displacement mapping moves the vertices.
Bump mapping only changes the lighting, displacement mapping actually changes the geometry (so that silhouettes are correct).
Any answer like this is OK.

Question 7: Gamma Correction (9 pts)

Describe the standard procedure used to set the gamma correction value for a monitor.

Make 2 regions: one black and white, one gray. Make the black and white area have a percentage (typically 50% white), make the gray area have the same gray level. Adjust gamma so they look the same.

Question 8: Color Gamuts (10 pts)

8.A We use red, green, and blue for the additive primaries for displaying color. Explain why violet (which has an even shorter wavelength than blue) might have been a better choice.

Any one of:

- it would provide a broader color gamut
- it would make it easier to distinguish blue and violet more readily
- it would make it possible to show violet (whereas now we can only show blue)

8.B Give one reason that violet wasn't chosen as the 3rd primary.

Any one of:

- our eyes are less sensitive (so it would have to be brighter)
- it's too hard to produce hardware that shows violet
- (and I'd even accept) blue is more important in the real world

8.C If Violet was the third primary, many of the color representations we use would change. RGB would become RGV, for example. Describe what would happen to the CIE XYZ color system and the HSV color system.

XYZ doesn't change (it's based on perception)
The H values change since the color wheel would now include violet (rather than blue)

Question 9: Lighting and Shading

A scene is lit by a single directional light source coming down vertically (like the sun at high noon). Your eye is on the Y axis, looking downward (the light can shine through you). You are looking at the square floor, which is a single, large square polygon centered at the origin.

Describe the lighting on the polygon for each of the following material properties. You might want to draw a sketch of the lighting on the square, or describe it in words. Notice that we've answered one part for you.

9.A The floor is completely diffuse (no specularities), and shaded with Gouraud Shading

The entire floor would appear the same color.

9.B The floor is completely specular (no diffuse), and is shaded with Gouraud Shading

The floor would appear all the same color
(since each vertex has the same angle, and lighting is only computed at the vertices)

9.C The floor is completely diffuse (no specularities), and shaded with Phong Shading

The entire floor is one color.

9.D The floor is completely specular (no diffuse), and is shaded with Phong Shading

The floor has a bight spot in the center and gets darker (radially outward)

9.E If the angle of the light is changed, and the brightness of the light is adjusted such that the average brightness of the square is the same, which of the above 4 answers would be different?

B and D
(A and C would still be a constant color)