- Print your name on the cover of the exam booklet. If you need extra space, write "on the second booklet" on the last page of the first booklet and staple them together when you hand it in.
- Clearly label the problem number on the booklet(s)
- Carefully read each question before answering it
- **There are 2 pages 12 questions 100 points total in this exam.**
- **There are 20 point extra credit question.**

Strategy: Read through the entire question before you begin it. If you get bogged down on a question, go on and come back later. Even if you don't think you know the entire answer to a question, do what you can in order to get partial credit. If something isn't clear to you, ask.

Part 1: Odds, Ends, and Concepts (20 points)

1. (1 point) What is the most amusing bug you've written in this class?

   For me the instructor, it took me a day to figure out that glFloat was different from float. When I did not cast the type from float to glFloat, nothing would be shown on the screen. I always pay attention to all warnings in OpenGL code since then.

2. (1 point) What is a pixel?

   A pixel is a physical point in a raster image or the smallest addressable element in a display device.

3. (2 points) Who was Ivan Sutherland in computer graphics? What did he do?

   Ivan Sutherland is the inventor of the Sketchpad, an early predecessor of the graphical user interface that is used today. He did this work when he was a PhD student at the University of Utah.

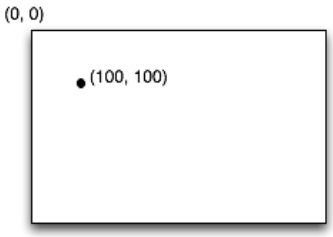
4. (2 points) What is the difference between interlaced and non-interlaced display? Why might you choose one over the other?

   A non-interlaced display is a type of display in which the lines are scanned sequentially from the top to the bottom of the screen. An interlaced one is a type of display that lines are scanned in two interwoven rasterized lines.

   For 2D display, a non-interlaced monitor tends to produce less flickers than interlaced; however, an interlaced monitor is useful for producing 3D stereoscopic images for showing the left and the right eye images accordingly.

5. (3 points) Where is the default (0, 0) on the screen defined by OpenGL? Where is the point (100, 100) going to appear on a screen with a resolution of (640, 480)? You can answer these questions by drawing the screen coordinates.

   (0, 0) is located at the upper left corner of the display.



6. (3 points) Two vectors can define a plane. Given two vectors, v1 (x1, y1, z1) and v2 (x2, y2, z2), what is the normal direction of the plane defined by these two vectors?

$$V1 \times V2 = \begin{vmatrix} i & j & k \\ x1 & y1 & z1 \\ x2 & y2 & z2 \end{vmatrix} = (y1z2 - y2z1)\, i + (x2z1 - x1\, z2)\, j + (x1y2 - x2y1)\, k$$

   therefore, the normal direction of the plane is

$$\left(\frac{y1z2 - y2z1}{L}, \quad \frac{x2z1 - x1\, z2}{L}, \quad \frac{x1y2 - x2y1}{L} \right),$$

   where

$$L = \sqrt{(y1z2 - y2z1)^2 + (x2z1 - x1z2)^2 + (x1y2 - x2y1)^2}$$

7. (3 points) Write a parametric equation for a sphere at the origin with radius R.

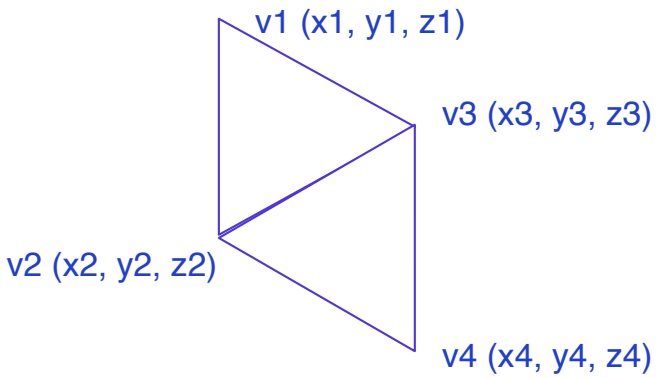
   $x = R \cos(\alpha) \sin(\beta)$

   $y = R \sin(\alpha) \sin(\beta)$

   $z = R \cos(\beta)$

8. (5 points) What is the split triangles and index triangles representations? Which one is better and why?

   Assuming a mesh is formed by two triangles represented using four points: v1 (x1, y1, z1), v2(x2, y2, z2), v3 (x3, y3, z3), and v4(x4, y4, z4)



Split triangle: (v1, v2, v3); (v2, v4, v3)
Index triangle: v1, v2, v3, v4; (1, 2, 3); (2, 4, 3)

Index triangle representation is better because it saves memory.

Part 2: Problem Solving (80 points)

9. (20 points)

(1) Express the homogeneous 3D transformation defined by the matrix

$$\begin{bmatrix} 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & 3 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

as a sequence of transformations in the following ways:

- **A rotation followed by a translation.**

```
[1 0 0 2] [0 -1 0 0]
[0 1 0 3] [1  0 0 0]
[0 0 1 4] [0  0 1 0]
[0 0 0 1] [0  0 0 1]
```

- **A translation followed by a rotation.**

```
[0 -1 0 0] [1 0 0  3]
[1  0 0 0] [0 1 0 -2]
[0  0 1 0] [0 0 1  4]
[0  0 0 1] [0 0 0  1]
```

(2) Write the OpenGL code for performing the transformation in (1) using glRotatef and glTranslatef.

A rotation followed by a translation:

glPushMatrix();

glTranslatef(2, 3, 4);

glRotatef(90, 0, 0, 1);

DrawSomethingHere();

glPop();

A translation followed by a rotation

glPushMatrix();

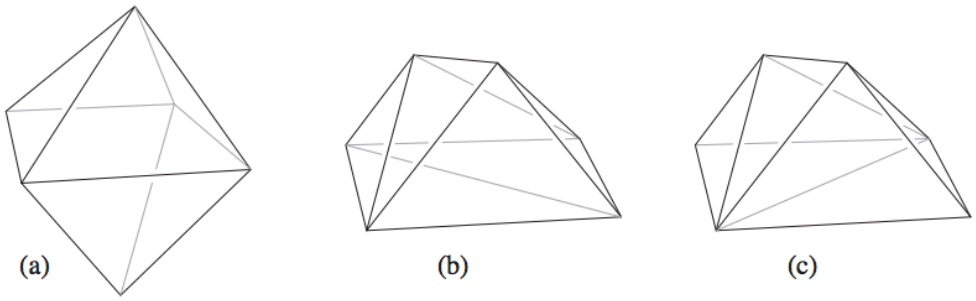
glRotatef(90, 0, 0, 1);

glTranslatef(3, -2, 4);

DrawSomethingHere();

glPop();

10. (20 points) Look at these three meshes:

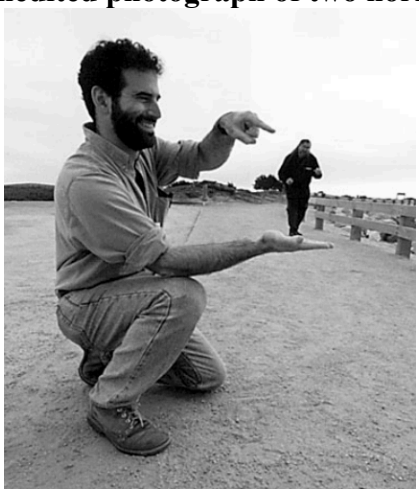


(1) Which of these share the same geometry and why?

(2) The following incomplete triangle neighbor structure describes one of these meshes. Indicate which one it is, and complete the table so that it describes the whole mesh.

	tris[]			tNbr[]		
0	0	5	1	1		4
1	0	4	5	2		0
2	0	3	4	3		1
3	0	2	3	4		2
4	0	1	2	0		3
5						
6						
7						

11. (20 points) Here is an unedited photograph of two normal-sized people:



The image above is 450 pixels high, and the two heads measure 90 and 15 pixels high. Assume all heads are 30 cm high. The image on the camera's film plane is 24 mm high.

(1) If I know that the person in the foreground is 2 meters from the camera, what is the camera's image plane distance (the focal length) and how far away is the other person?

*At the distance of the close person, 90 pixels correspond to 0.3 m. At the same distance, 450 pixels correspond to 1.5m. So the image is 1.5m high at 2m – a ratio of 3:4. When the image is 24 mm high it is at a distance of (4:3) * 24 = 32 mm. This is the image plane distance. The second person is 6 times the distance of the first person, so 12 meters.*

(2) If I know that the two people are standing 20 meters apart, what is the image plane distance and how far from the camera is the closer person?
(Photo courtesy of Seth Teller, who says, "no computers were used to make this picture.")

Let the distance to the near person be d. The far person is at distance 6d. The distance between the people is then 5d=20 meters. So d = 4 meters. This distance is twice that in the part 1, so the image plane distance is also doubled and it is 64 mm.

12. **(20 points)**

(1) You start by considering the kinds of splines you know about. Write out a matrix that looks like this and fill in yes or no in each space to indicate which type of spline has which properties.

	C^1 continuity	C^2 continuity	Stays in convex hull of control points	Interpolates control points	Can intersect with itself
Hermite	Y	N	Y	N	Y
Cubic Bezier	Y	Y	Y	N	Y

(2) Write the OpenGL code that will plot the cubic Bezier curve formed by four control points: (0, 0), (0, 1), (1, 1), (1, 0). You only need to write the drawing routine.

Please check out the example online.