Student #:
Name:

Write down answers in-between questions. Please answer using short sentences.

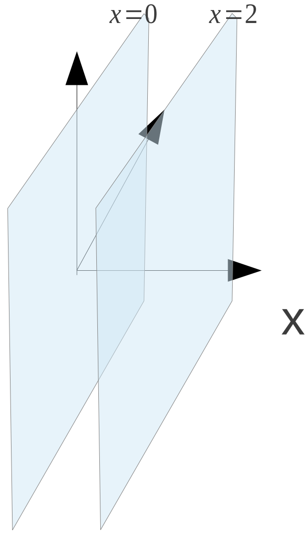
1. What is the equation of the plane through 3D points (-1,0,0), (0,1,0), and (0,0,1)? What is the normal vector to this plane?

2. Given a rigid transformation matrix R of which the linear part Q is an orthonormal matrix, verify that the inverse of orthormal matrix is as below. (Use the property that the inverse of an orthonormal matrix is its transpose.)

$$R = \begin{bmatrix} Q & \mathbf{u} \\ 0 & 1 \end{bmatrix}, \quad R^{-1} = \begin{bmatrix} Q^T & -Q^T\mathbf{u} \\ 0 & 1 \end{bmatrix}$$

3. What are the ray parameters of the intersection points between ray $(1,1,1) + t(-1,-1,-1)$ and a sphere centered at $(-2,-2,-2)$ with radius 1?

4. Calculate the interval of the ray parameters of the intersection points between ray $(1,1,1)+t(-1,-1,-1)$ and a slab defined by two planes shown below.



5. (a) Write down the 4×4 3D matrix to move by (x_m, y_m, z_m).

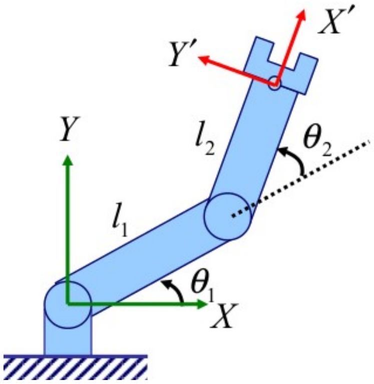
(b) Write down the 4×4 3D matrix to rotate by an angle θ about the z-axis.

(c) Write down the 4×4 rotation matrix M that maps the orthonormal 3D vectors $\boldsymbol{u}=(x_u, y_u, z_u), \boldsymbol{v}=(x_v, y_v, z_v)$, and $\boldsymbol{w}=(x_w, y_w, z_w)$, to orthonormal 3D vectors $\boldsymbol{a}=(x_a, y_a, z_a), \boldsymbol{b}=(x_b, y_b, z_b)$, and $\boldsymbol{c}=(x_c, y_c, z_c)$, so $M\boldsymbol{u}=\boldsymbol{a}, M\boldsymbol{v}=\boldsymbol{b}$, and $M\boldsymbol{w}=\boldsymbol{c}$.

6. Describe in words what this 2D transformation matrix does:

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

7. Write down the transformation matrix T of the tool (at X', Y') in terms of 2D rotation matrix R_θ and 2D translation matrix $T_{(tx,ty)}$. For example, your answer should look something like $T = R_{\theta_3} T_{(0,l_3)}$.



8. Fill in the blanks below in the source code for the incremental linear interpolation algorithm that calculates qRow=cx*x + cy*y+ck for all pixels.

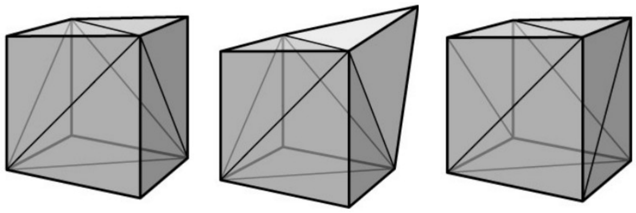
```
linEval(xl, xh, yl, yh, cx, cy, ck) {

   // setup
   qRow = cx*xl + cy*yl + ck;

   // traversal
   for y = yl to yh {
      qPix = qRow;
      for x = xl to xh {
         output(x, y, qPix);
         qPix +=
      }
      qRow +=
   }
}
```

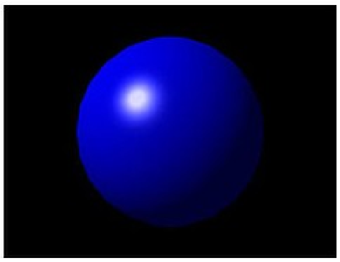
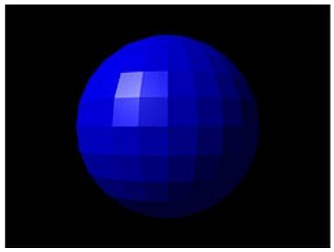
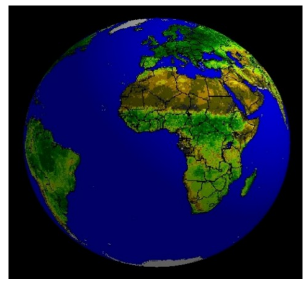
$c_x = .005;\ c_y = .005;\ c_k = 0$
(image size 100x100)

9. Which of these share the same topology? Which share the same geometry?



(a) (b) (c)

10. Look at each of the following images rendered in a pipeline system. For each one, answer the following questions. Describe in words; you don't need to write down any equations. You can assume that the depth test is done automatically after the fragment stage. All three images were generated from the same triangular mesh using the Phong, flat, and gouraud shading techniques, respectively. Some attributes you might need include positions, normals, colors, texture coordinates, or scalar values. Assume all three spheres have visible texture maps. Write down all the assumptions that you had to make.

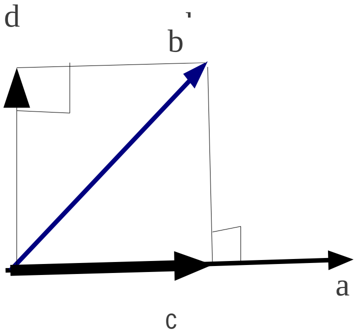
(a) Explain what per-vertex attributes need to be passed from the application to the vertex stage.

(b) Describe the computations that need to be done at the vertex stage.

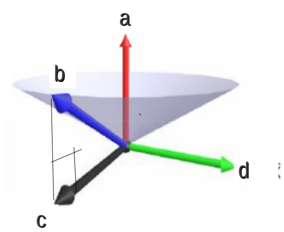
(c) Explain what attributes are interpolated by the rasterizer for the fragment stage.

(d) Describe the computations that need to be done at the fragment stage.

11. Represent vector $\boldsymbol{c}$ and $\boldsymbol{d}$ in terms of vector $\boldsymbol{a}$ and $\boldsymbol{b}$ using the dot product operator (·) and the length operator (| |).



12. Briefly explain why || d || == || c || when $d = a \times b$ and || a ||=1.



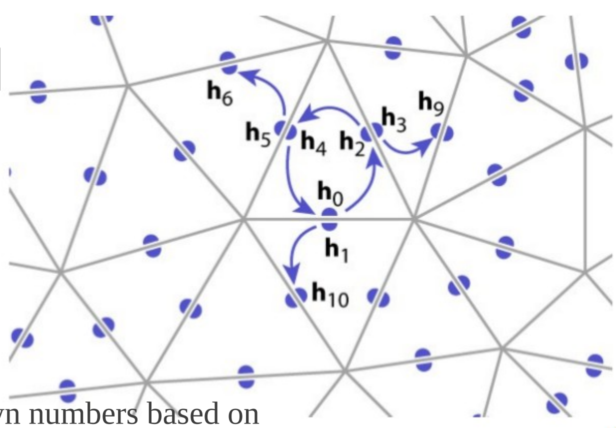
13. Derive the average storage requirement (bytes per vertex) of the triangle strip representation assuming that a vertex contains a position and a normal (4byte float variables) and that the number of triangles is twice the number of vertices on average.

14. Fill in the blanks below of the algorithm that enumerate all edges adjacent to vertex v.

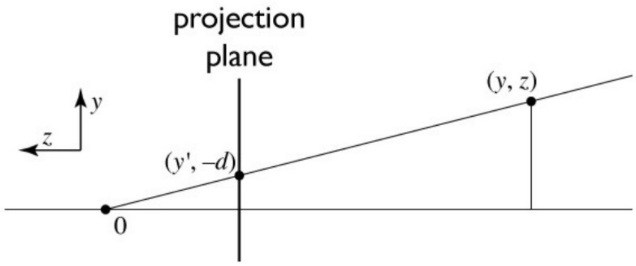
```
EdgesOfVertex(v) {
h = v.h;
do {
        h = [          ]
    } while (h != v.h);
}
```

	pair	next
hedge[0]	1	
hedge[1]	0	
hedge[2]	3	
hedge[3]	2	
hedge[4]	5	
hedge[5]	4	
	⋮	

Write down numbers based on the right figure



15. Write down the 3×4 projection matrix that maps a 3d point (x,y,z) to (x',y')?
Hint: similar triangles, homogeneous coordinates



16. Briefly explain why the measured dynamic range of the same display can differ depending on lighting conditions.

17. [Hidden surface removal] Briefly explain the main downside of the painter's algorithm, and then explain the alternative algorithm that is unanimously used in real-time applications such as games.

18. Fill in the blanks below using glRotatef(angle, axis_x, axis_y, axis_z) and glTranslatef(amount_x, amount_y, amount_z) function.

```
void MyDisplay()
{
    glOrtho(-1.0, 1.0, -1.0, 1.0, -1.0, 1.0);
    glViewport(0, 0, 300, 300);
    glClearColor(1.0, 1.0, 1.0, 1.0);
    glClear(GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT);
    glColor3f(0.5, 0.5, 0.5);
    glLoadIdentity();
    gl
    gl

    double w=sqrt(2*(0.5*0.5))*0.5;
    glBegin(GL_POLYGON);

        glVertex3f(w,w,0);
        glVertex3f(-w,w,0);
        glVertex3f(-w,-w,0);
        glVertex3f(w,-w,0);
    glEnd();
    glFlush();
}
```