COMP 410/510-Computer Graphics
Spring 2021, Endterm

(9 questions over 110 points)

Instructions: This is a take-home exam. You are required to complete this exam on your own without any help from anyone else. The effort in the exam must thus belong completely to you.

In order to get full points from a question, you must properly explain your answer whenever you are asked to do so in the question. Since this is a take-home exam, how you formulate and explain your answer will also be taken into account while grading.

Write down the answers on paper, take photo and submit to Blackboard preferably as one single pdf file until 28 May, Friday, 11:59pm.

1. (10pts) Name the specific step in the pipeline, where each of the following tasks is carried out (in other words, match the given tasks with the steps of the pipeline; *vertex processing*, *clipping and primitive assembly*, *rasterization* or *fragment processing*):

Gouraud shading:

Eliminating vertices that are outside the view volume:

Texture mapping:

Transformation:

Hidden surface removal (using depth buffer):

Bilinear interpolation (of attributes):

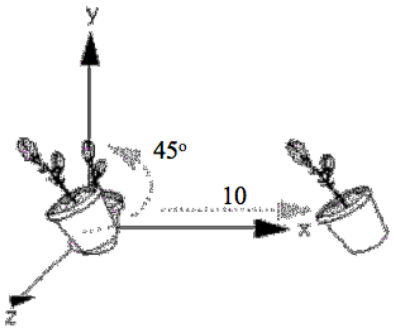
Scan conversion (Filling in lines and triangles):

View normalization:

Coloring pixels:

Phong shading:

2. (10pts) Consider the figure below. Write down the 4×4 affine transformation matrix that moves the object accordingly. Note that the amount of rotation is 45 degrees (around z-axis), followed by a translation of 10 (along x-axis). Explain your answer.



3. (10pts) Consider rotating an object **clockwise** around the fixed point (1,1,1) and the vector $\boldsymbol{v} = \boldsymbol{i} + \boldsymbol{j} + \boldsymbol{k}$. Write down the corresponding 4×4 transformation matrix. Explain your answer.

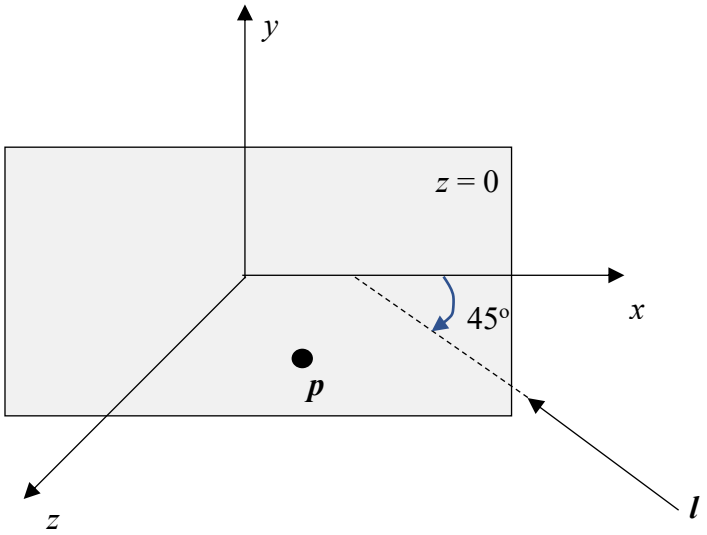
4. (20pts) Suppose that the center of projection is at point **p** = (1,0,0).

a) Write down the 4×4 matrix that gives the perspective projection onto $x = 0$ plane.

b) Write down the 4×4 matrix that gives the perspective projection onto $x = y$ plane.

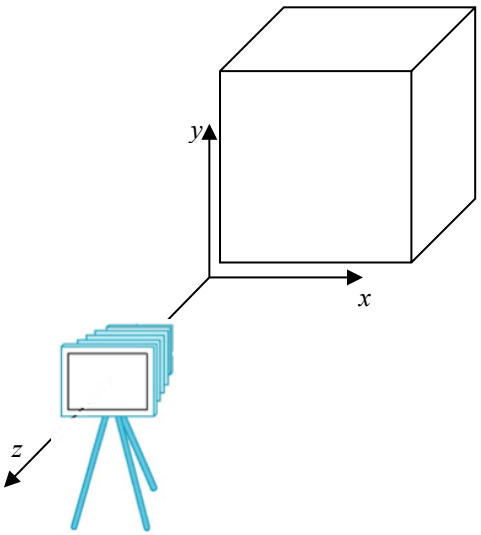
Explain your answer.

5. (10pts) Consider the planar surface z = 0 below, which is lit with a directional light source $\boldsymbol{l}$ = (-1, 0, -1, 0). Find the point on this surface, at which the specular component of the reflection is maximum with respect to the viewer that is located at point $\boldsymbol{p}$ = (1, 0, 1, 1). Explain your answer.



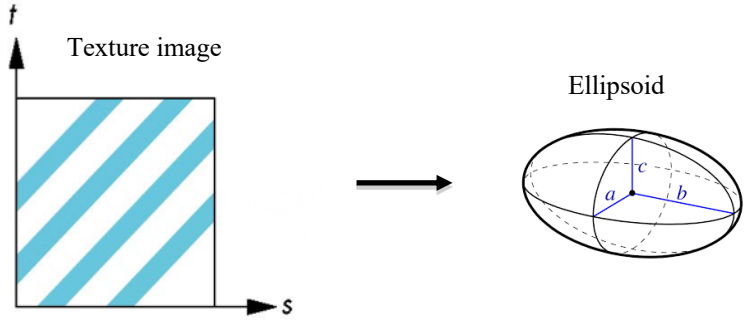
6. (10pts) Consider the following configuration, where the camera is located at $z = d$ ($d > 0$) looking along the negative z-axis direction. Assume the default **orthographic** projection. Assume also that the cube is precisely aligned with the coordinate axes (that is, each face of the cube is either parallel or perpendicular to the axes).

First **define** what the term "culling" means in graphics. Then **determine** which faces of the cube below are rendered and which faces are not, if culling is applied. **Explain** mathematically why. Consider only the outer front faces of the cube.

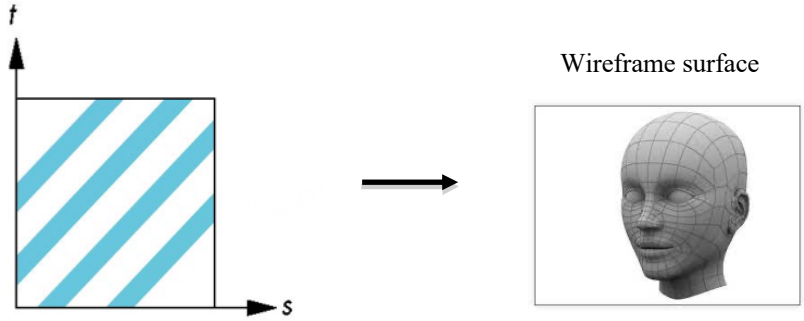


7. (10pts) Find two functions $s(x,y,z)$ and $t(x,y,z)$ that would map a texture image onto an ellyisoid with radii a, b and c (see below) such that, for a given point (x,y,z) on the surface, the texture coordinates s and t will be given by $s = s(x,y,z)$ and $t = t(x,y,z)$.

Hint: Think of the parameterization of an ellypsoid.



8. (10pts) Explain how one can use the mapping obtained in **Question 7** to map the same texture onto the human head model below, which is a closed wireframe surface. Describe the method. Discuss shortcomings of the method that you describe if there are any.



9. (20pts)

a) Consider orthographic projection and suppose that the view volume is given by the intersection of the planes $z = 2$, $z = 4$, $y = 1$, $y = 2$, $x = 2$ and $x = 5$. Write down the view normalization transformation that converts this projection (viewing) into orthographic projection with the default view volume, i.e., the cube centered at the origin with sides of length 2. Explain your answer.

b) Consider the perspective projection with COP at the origin and the projection plane at $z = -1$. Suppose also that the view volume is given by the frustum bounded by near plane $z = -2$ and far plane $z = -3$ with 120 degree field of view (as determined by the planes $x = \pm \sqrt{3}z$ and $y = \pm \sqrt{3}z$). Write down the view normalization transformation that converts this projection (viewing) into orthographic projection with the default view volume, i.e., the cube centered at the origin with sides of length 2. Explain your answer.