EXAM IN

COMPUTER GRAPHICS

TSBK07

(TEN1)

Time:	21th of October, 2022, 8-12
Room:	TER3
Teacher:	Ingemar Ragnemalm, visits the exam around 10, also available by phone.
Allowed help:	None
Requirement to pass:	Grade 3: 21 points Grade 4: 31 points Grade 5: 41 points ECTS: C: 21 points B: 31 points A: 41 points

Answers may be given in swedish or english.

- Wish us luck!
- I wish you skill!
[Martin Landau, ”Mission Impossible”]

1. OpenGL and shader programming

a) What is a shader? Explain the concept and describe the two most common kinds in detail concerning their use and role in the graphics pipeline.

(2p)

b) You have a variable in your host OpenGL program, *GLfloat time*, which holds the time. This value is needed in your vertex shader to control an animation. Describe how the host OpenGL program sends the variable to a shader program. Clarify how variables are identified. A code-like example is preferred.

(2p)

c) In order to produce a normal matrix, a transformation matrix for normals, we can take the inverse transpose of... which matrix?

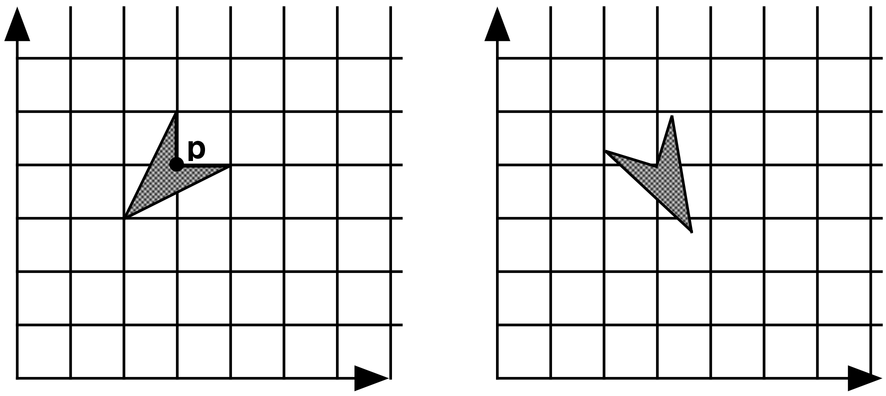
(1p)

2. Transformations

a) Describe how to implement the look-at function. It is specified with the point you look at, **l**, the point you look from **p**, and an up-vector **v**. Focus on the transformations involved.

(3p)

b) In the figure, a 2D shape is shown together with a point **p**. Produce a sequence of 3x3 matrixes that define a transformation that rotates the shape (or anything else) around **p** by an angle ϕ. The contents of each matrix should be given, using the symbols **p** and ϕ as appropriate. You don't have to multiply the matrices together.



Original shape and position, and the point p that the shape is rotated around

After transformation

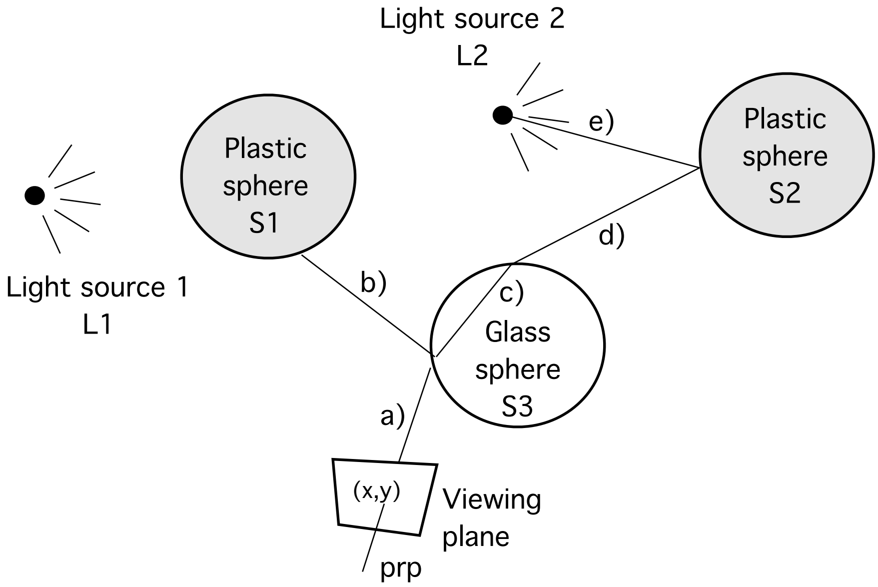
(3p)

c) What operation does the following matrix perform when multiplied with a position vector (column vector to the right)?

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

(2p)

3. Light, shading and ray-tracing



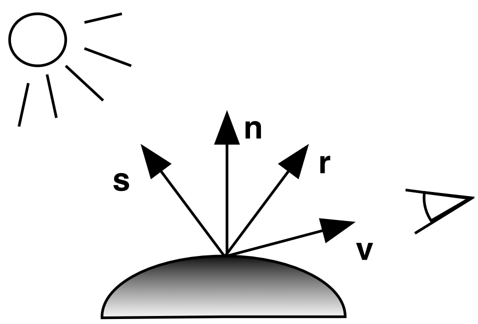
a) A couple of rays (a-e) used to calculate the pixel (x, y) are shown in the figure. Certain rays to L1 and L2 are missing. Which ones? You should clearly describe them by name or function.

(2p)

b) What recursion depth is needed to make the ray sequence shown above produce a non-black color? (Recursion depth = 0 means that only the primary ray is cast.) If any part of the sequence illustrated does not count for the depth, explain why.

(3p)

c) Write a formula for the 3-component light model allowing for multiple light sources. Use the symbols of the following figure:



(3p)

4. Surface detail

a) Linear coordinates (u, v) can be defined by

$$x = u$$
$$y = v$$

Write formulas for linear (planar) texture mapping, mapping x, y, z to texture coordinates (s, t), normalized to the interval [0, 1].

(2p)

b) A skybox is an easy way to get an illusion of an environment at (for practical purposes) infinite distance. Altough the principle is simple, mapping a texture on a cube which works as a backdrop, there are several important issues that have to be considered in order to make a good skybox. Give *three* important issues. A brief sentence for each should suffice.

(2p)

c) When using mip-mapping, several different interpolation modes can be specified. Give an overview of the modes, using a figure to clarify what values are interpolated between.

(3p)

5. Curve generation

a) What significant features characterize the Catmull-Rom spline (cardinal splines)? The answer should describe the resulting curve with respect to its control points. Plot a figure of how its blending functions look.

(2p)

b) Two segments of a 2D spline is given by the following functions:

$p_x(u) = -3 + 6u - 2u^2$
$p_y(u) = u + u^2$
$q_x(v) = 1 + 4v + 2v^2$
$q_y(v) = 2 + 6v - 2v^3$

What continuity criteria do these segments fulfill for u=1, v=0?

(3p)

6. Miscellaneous

a) Outline a method for generating a random terrain. Any method may be chosen as long as the resulting terrain is reasonably good. Is the method suitable for any of the following?

- Creating a terrain that can be repeated seamlessly to a seemingly infinite world
- After creation, scaling up to a higher resolution using the same method as needed
- Controlling frequency variations in detail

Explain why the method is or is not suitable for each feature.

(4p)

b) Anti-aliasing can be performed by supersampling. Explain why supersampling reduces aliasing, and what behavior you must assume for the signal (the image). The explanation should involve arguments in frequency space.

(3p)

7. Collision detection and animation

a) Describe how 2D collision detection can be performed using the Separating Axis Theorem (SAT). (It is recommended to use figures.)

(3p)

b) To get good camera placement in an animation, collision detection is vital for the camera. Describe how you can do camera-polyhedra collision detection.

(2p)

8. Visible surface detection and large worlds

a) Describe mathematically how you can perform frustum culling for an object for which an enclosing sphere is given. How many tests are needed? The description should reflect the coordinate systems involved.

(3p)

b) Using a figure, describe how the ”cells and portals” VSD method works. What kind of environments is this method most suited for?

(2p)