EXAM IN

COMPUTER GRAPHICS

TSBK07

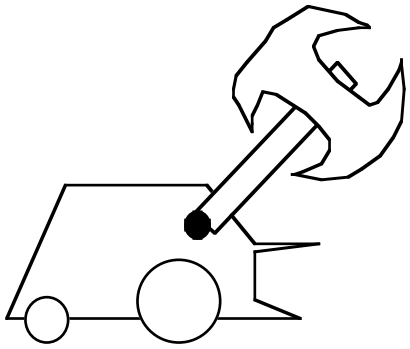
Time:	5th of June, 2009, 14-18
Room:	G33/G35/G37
Teacher:	Ingemar Ragnemalm, visits around 15 and 17
Allowed help:	None
Requirement to pass:	Grade 3: 21 points Grade 4: 31 points Grade 5: 41 points ECTS: C: 21 points B: 31 points A: 41 points

Answers may be given in swedish or english.

Good luck!

1. OpenGL programming

a) A special-purpose vehicle is shown in the figure below.



A special-purpose vehicle

Your task is to write the code for animating this vehicle. It has three moving parts: the big axe in the front and two axes (plural of axis, not axe) with wheels.

The code for drawing the vehicle parts is given as the functions drawBody(), drawAxe() and drawWheels(). The function drawWheels() will draw the wheels in the scale of the front pair, while the rear wheels should have half the radius. All are drawn in their local coordinate systems.

The origin for the model is at the bottom, centered, facing negative Z.

The robot moves freely in the horizontal plane; position is given as $\mathbf{p_x}$ and $\mathbf{p_z}$, with rotation α.

The axe is located at $\mathbf{y_a}$ above the robot origin, $\mathbf{z_a}$ in front of the origin and its rotation is β. The default ($\beta = 0$) rotation is vertical.

The wheel axes are at height $\mathbf{y_1}$ and $\mathbf{y_2}$, placed horizontally at $\mathbf{z_1}$ and $\mathbf{z_2}$. They rotate by ∂_1 and ∂_2.

Write OpenGL code for drawing the vehicle using the calls above and standard OpenGL calls.

You should not write code for the entire program, only for the parts that deals with the drawing of the vehicle.

(3p)

b) The following GLSL code contains errors. Which ones? You need to find at least three errors for full score.

```
#include <stdio.h>

int main(int argc, char *argv[])
{
      vec4 gl_Test = gl_Position.rxsz;
      if (gl_Test == vec4(0))
            printf(”Zero vector\n”);
      gl_FragCoord = gl_Test;
}
```

(3p)

2. Transformations

a) In a 3D world, you want to rotate around a given axis by an angle ∂. The axis is known to be aligned with the Y axis, and passing through a point **p**.

Give a sequence of 4x4 matrixes, each defining one basic geometric transformation (translation, rotation around origin, mirroring, scaling, skewing), that define a transformation that produces the desired rotation. You don't have to multiply the matrices together, but the multiplication order for transformation of a point should be given.

(3p)

b) The following matrix can be used for perspective projection:

$$\begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & -z_{vp} & z_{vp} \cdot z_{prp} \\ 0 & 0 & -1 & z_{prp} \end{bmatrix}$$

Show, using the geometry of the fundamental pinhole camera model, that this matrix will perform perspective projection.

(4p)

3. Curve generation

a) Both Bézier and Catmull-Rom splines are defined by blending functions. Illustrate by a figure the approximate look of the blending functions for either type. What properties does each spline type have, and how do the blending functions relate to these properties? What relevance do the zero crossings for either spline have for their behavior?

(4p)

b) The fundamental principle for the Bresenham line drawing algorithm is a certain decision. What decision is that, and by what measure is it taken? (You do not have to derive the formulas.)

(2p)

4. Surface detail

a) Cylindrical texture mapping has been described as follows:

$$u = \tan^{-1}(y/x)$$
$$v = z$$

Suggest two ways to improve the mapping as applied to a single point.

(3p)

b) If cylindrical or spherical mapping is done by vertex, another problem occurs for a whole polyhedra model. What is that problem and how can it be solved?

(2p)

5. Light, shading and ray-tracing

a) Describe how shadows are generated in ray-tracing.

(2p)

b) Describe how shadows are generated in radiosity.

(3p)

c) Write the formula for the three-component light model. Define all included vectors using a figure.

(3p)

6. Miscellaneous

a) Derive how you can mirror a directional vector **a** over a plane given by the normal vector **n**.

(3p)

b) Outline a method for generating a realistic random terrain. It is not sufficient to simply fill an array with random values. Why?

(3p)

7. Collision detection

a) Using a figure, give examples of two depth cues that are useful in 2D (pseudo-3D) graphics.

(2p)

b) Suggest two bounding shapes suitable for the broad phase.

(2p)

c) Outline a method to accelerate collision detection for scenes with a large number of objects.

(2p)

8. Visible surface detection and large worlds

a) A common VSD method has problems with transparency. Describe the problem and a remedy.

(2p)

b) In what way are view plane oriented billboards preferrable to viewpoint oriented billboards?

(2p)

c) Describe how frustum culling can be applied to an object. The test should be given in mathematical form. Define the symbols you use in a figure.

(2p)