Final Exam - 1996

**Instructions to Candidates:**

The exam accounts for 50% of the total marks for the subject.

Candidates should attempt all questions 1 to 6.

Marks for each question are shown. Total marks for the exam is 60.

**Question 1**

(a) Each of the right-handed, three-dimensional coordinate systems below has one axis missing. State which axis is missing and whether the missing axis points into or out of the page.

(b) A planar polygon P1 has the four vertices A(3,2,-12), B(7,1,-2), C(6,6,5) and D(4,6,-1). Work out the plane equation of the plane in which the polygon lies.

(c) A different planar polygon P2 has the three vertices E(5,4,-1), F(7,0,5) and G(9,2,5). Work out the plane equation of the plane in which the polygon lies.

(d) Assume a viewer is positioned an infinite distance along the positive z axis looking towards the origin along the z axis with up in the direction of the positive y axis. Which polygon from (b) and (c) would they see at the pixel (6,2)? Show your working.

(e) If the hidden surface problem was to be solved by back-to-front drawing of polygons, in which order would P1 and P2 have to be drawn to get a correct hidden surface solution for the viewing arrangement of (d)? Justify your answer.

(f) A problem which occurs in two-dimensional polygon clipping is deciding which side of a clip edge a point lies on. Given the clip edge A(3,9) - B(2,5) determine which side the point (2,3,7,2) lies on. Assume the polygon lies to the left of the clip edge AB. Show your working.

\[1 + 2 + 2 + 1 + 2 + 1 = 9 \text{ marks}\]
Question 2

(a) Three-dimensional computer graphics makes extensive use of $4 \times 4$ transformation matrices — rather than $3 \times 3$ transformation matrices. Likewise, two-dimensional computer graphics makes extensive use of $3 \times 3$ transformation matrices — rather than $2 \times 2$ transformation matrices. Explain why.

(b) Give the transformation steps and the combined transformation matrix (CTM) which transforms the hand shown below on the left into the hand shown below on the right.

(c) Explain the difference between a modelling transformation and a viewing transformation. Use diagrams in your explanation.

\[(3 + 5 + 2 = 10 \text{ marks})\]

Question 3

(a) The \textit{scan-line algorithm} for efficient rasterization of concave polygons uses an \textit{edge table} and an \textit{active edge table}. Give the algorithm, explain what these “tables” are and explain how they are used to realise an efficient algorithm.

(b) Show the state of the edge table and the active edge table in the algorithm you gave as answer to (a) at scan lines $y = 1$, $y = 3$ and $y = 4$ for the polygon given below. Indicate the pixels which will be intensified on each of those scan lines.

(c) Some 3D graphics libraries only provide a convex polygon primitive. Explain the efficiencies which can be achieved by handling only convex polygons.

(d) If a graphics library only has a convex polygon primitive but an application requires concave polygons, such as that in (b), what approach may be taken?

\[(5 + 4 + 2 + 2 = 13 \text{ marks})\]
Question 4

A programmer is creating a three-dimensional animation in which the star attraction is a toy juggler. She is starting with a simple wireframe box model which consists of a torso, two arms, two legs and a head as shown below. An arm consists of an upper and lower arm. The model contains the following joints: a left and right hip, which can rotate around the x-axis; a left and right shoulder, elbow and wrist, which can rotate around the z-axis, and a neck joint which can rotate around the y-axis. A rotation angle is stored for each joint. The depth of the torso and the limbs is 2, centred on the y axis.

(a) Describe a hierarchical data structure, including details of nodes, suitable for representing the juggler.

(b) One of the libraries being used includes a function `glutWireCube(float size)` which draws a cube of side length size centred at the origin. Using this function write a function

```
myWireBox(float width, float height, float depth)
```

which draws a wire box of dimensions width, height and depth at the current drawing position with the current drawing orientation in the current drawing colour.

(c) Assuming the rotation angle of each joint about its rotation axis is not constrained in any way, write a function

```
void display(/* your arguments here */)
```

which uses the data structure you gave as answer to (a) and OpenGL modelling transformations, OpenGL modelview matrix stack manipulation functions and `myWireBox` to render the toy juggler. You should provide appropriate arguments to display (using your answer to (a)). Assume the viewing parameters, window initialisation, etc., have all been correctly set-up.

(d) The animator has decided the juggling balls will move along projectile motion paths as if under the influence of gravity. The diagram below shows the juggler just before the ball leaves the left hand. The juggler’s right arm and hand stay in the position shown to catch the ball. The scale is metres (it is a big toy!). If the ball is in the air for two seconds what must be the horizontal and vertical velocity of the ball when it leaves the left hand. What is the maximum height of the ball? Assume gravity is 10.0 m/s².
(e) The storyboard below shows some keyframes in the motion of the juggler throwing and catching one ball. Assuming constant angular velocity around each joint and linear interpolation between key frames, draw parameter curves for the rotations about the juggler’s right shoulder, right elbow and right wrist. The juggler at t=0 is the same as shown in the diagram in (d) above.

(5+1+4+3+3 = 16 marks)

**Question 5**

OpenGL supports a range of rendering modes. In the diagram below a sphere has been rendered in five different ways. Describe the most important features of each rendering, explain what the settings or modes of the OpenGL state machine need to be to produce it and give the OpenGL command which applies to each setting or mode required.

(6 marks)

**Question 6**

Lighting in OpenGL is performed per vertex based on the following equation

\[ I_\lambda = O_{c_\lambda} + I_{a_\lambda}O_{a_\lambda} + \sum_{i=1}^m A_i S_i[I_{a_\lambda}O_{a_\lambda} + I_{d_\lambda}O_{d_\lambda}\text{max}(L_i N, 0) + I_{s_\lambda}O_{s_\lambda}\text{max}(R_i V, 0)^n] \]

Explain what you understand of the equation.

(6 Marks)

**THE END**