Computer Graphics

Date: Wednesday 27th May 2009  Time: 14:00 – 16:00

The Paper is in TWO SECTIONS

SECTION A is compulsory.
SECTION A must be answered on the Question Paper
Only answers written in the boxes on the Question Paper will be marked

You should also answer any two questions from Section B

Answer EACH of SECTIONS A and B in a new book.
Each Section is worth 20 marks

All question papers to be returned

The use of electronic calculators is not permitted.
SECTION A

Section A comprises of multi-choice questions and therefore cannot be published.
B1. **Note: You are expected to illustrate your answers to each part of this question, where appropriate, with clearly-drawn diagrams and sketches.**

a) Explain, using suitable illustrated examples to accompany your answer, what is meant by the following terms:

- Cartesian coordinate system
- Vector
- Vector dot product
- Vector cross product

(8 marks)

b) Why do we use 4x4 matrices to represent coordinate transformations in 3D space?  
(2 marks)

c) Give the 4x4 matrices which achieve the following effects:

- a translation by (1,5,2)
- a reflection about the Y axis
- a rotation about the X axis by 45 degrees

(3 marks)

d) What is meant by the statement “transformations are not commutative”? (2 marks)

e) Explain how complex transformations can be created from collections of simple transformations, illustrating your answer by showing how to derive a transformation to perform a rotation about an arbitrary vector in 3D space which does not pass through the origin.  
(5 marks)
B2.  Note: You are expected to illustrate your answers to each part of this question, where appropriate, with clearly-drawn diagrams and sketches.

a) What is “double buffering” and why is it necessary? (4 marks)

b) Suppose you were designing a graphics card which would support a double-buffered display of up to 4096 x 4096 pixel resolution, at a maximum colour depth of 32 bits. How much display memory would you need? Justify your answer. (2 marks)

c) Explain the standard method for solving the problem of hidden surface removal, illustrating your answer using an example scene which comprises two partially overlapping triangles, where part of one triangle is nearer to the viewer than the other triangle. (6 marks)

d) Comment on the efficiency of the method you described in part (c), and mention any undesirable effects that the method sometimes exhibits, and how to address them. (2 marks)

e) You are writing an application program which will allow a user to interact with a large hierarchically-structured model. The user wishes to take a full-screen screenshot of the application, to email to a colleague. What graphics file format would you recommend for this, and why? (2 marks)

f) One particular operation you want the user to be able to perform is “picking”, where the user can point at a piece of the model displayed on the screen, and have the application program highlight that piece of the model, and display its name. Discuss how this picking operation might be implemented using a raster display, and a vector display, and comment on the relative merits of each method. (4 marks)
B3. **Note:** You are expected to illustrate your answers to each part of this question, where appropriate, with clearly-drawn diagrams and sketches.

a) What is meant by the terms “modelling” and “rendering”. Why is useful to separate these two concepts? (2 marks)

b) “OpenGL guarantees to correctly render polygons only if they are convex.”

Explain what this statement means, and illustrate your answer with examples of convex and concave polygons. Describe one method for determining if a polygon is convex or not. (4 marks)

c) If you have a polygon which is known to be non-convex, what would you need to do to ensure that OpenGL renders it correctly? (1 mark)

d) Derive a mathematical model which will allow you to compute the colour of a point on an object at a known position in 3D space, assuming it is lit by a single light source located at a known position in 3D space. In your model, describe the purpose and bounding values of any parameters you define. Illustrate your answer with diagrams. (8 marks)

e) You are using the model you defined in (d) to create an image of a large flat polygon. You would like the polygon to appear to have a complicated surface structure, rather like bubble-wrap plastic packaging material. Describe a technique that would allow you to achieve this visual effect without changing the original geometrical definition of the polygon. (5 marks)

B4. **Note:** it is essential that you illustrate your answers to each part of this question, where appropriate, with clearly-drawn diagrams and sketches.

a) Explain the principles in creating a “view” of part of a 2D world-coordinate space, displaying it in an area of a display screen. Specify any coordinate transformations that you would use to achieve this. (4 marks)

b) Why do we usually wish to apply clipping to a 2D or 3D view? (2 marks)

c) What do you understand by the statement “Modelling and viewing are duals”? Illustrate your answer with an example. (3 marks)

d) Explain the terms “orthographic projection” and “perspective projection”, illustrating your answer with examples. (4 marks)

e) Explain how perspective projection, onto a projection plane z=d, can be implemented using a 4 x 4 matrix. (4 marks)

f) What is “projection normalization”? And why is it necessary? (3 marks)

END OF EXAMINATION