UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2004

BEng Honours Degree in Computing Part III
MSc in Computing Science
MEng Honours Degree in Electrical Engineering Part IV
BEng Honours Degree in Information Systems Engineering Part III
MEng Honours Degree in Information Systems Engineering Part III
BSc Honours Degree in Mathematics and Computer Science Part III
MSci Honours Degree in Mathematics and Computer Science Part III
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the Associateship of the City and Guilds of London Institute
This paper is also taken for the relevant examinations for the Associateship of the Royal College of Science

PAPER C317=I3.16=E4.32

GRAPHICS

Friday 30 April 2004, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

1 Shading and Texture Mapping

a Briefly describe how Gouraud and Phong shading can be used to shade surfaces. What are their key differences? What are the advantages and disadvantages of both approaches?

b Explain how texture mapping and bump mapping techniques can be used to improve the visual realism of graphical scenes.

c A 2D square-shaped facet on the view plane is being rendered using Gouraud shading. The intensity at the lower left vertex v_1 is I_1, proceeding clockwise, the intensity at vertex v_2 is I_2, at v_3 is I_3 and at v_4 is equal to I_4. Derive an expression for the intensity of a general point inside the square-shaped facet.

d Given a square-shaped facet with the following vertex coordinates and intensities:

Point	Intensity
$\mathbf{v}_1$ = (100, 100)	100
$\mathbf{v}_2$ = (100, 200)	70
$\mathbf{v}_3$ = (200, 200)	80
$\mathbf{v}_4$ = (200, 100)	200

Use the expression developed in the previous part of the question to calculate the intensity at point $\mathbf{p}_1$ = (150, 150) and $\mathbf{p}_2$ = (101, 150).

e Assume that the square-shaped facet above is subdivided into two triangles, A and B. Triangle A is defined by vertices v_1, v_2 and v_4. Triangle B is defined by vertices v_2, v_3 and v_4. Again, calculate the intensity at point $\mathbf{p}_1$ = (150, 150) and $\mathbf{p}_2$ = (101, 150).

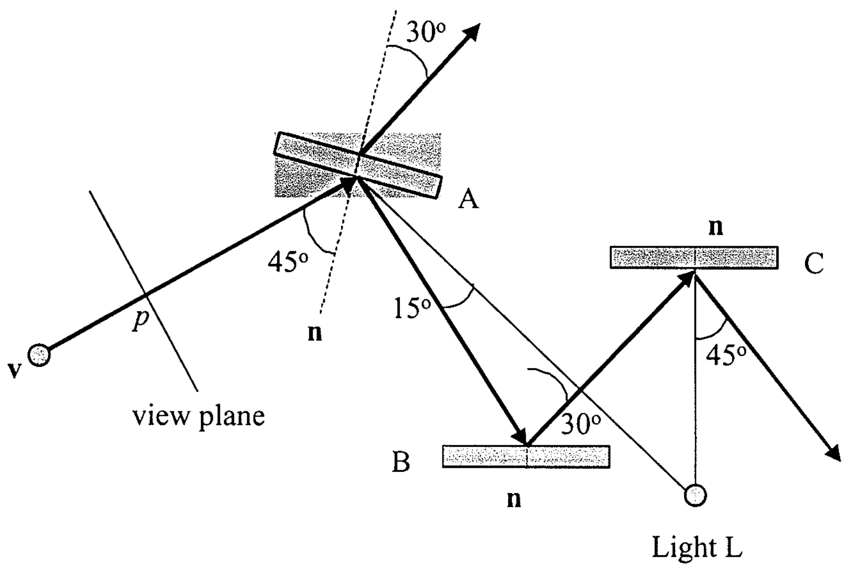
The five parts carry equal marks.

2 Ray tracing

a Explain which effects can be achieved with ray tracing and how these effects are created. Which effects cannot be created with ray tracing?

b Describe the use of two space subdivision methods for ray tracing and describe how they can be used to accelerate ray tracing.

c Assuming a monochromatic light source L, compute the intensity of pixel p in the figure below using ray tracing. Dotted lines labeled **n** are the normals to the surfaces. Use the following data: Intensity of light = 1.0, Intensity of ambient colour = 0.2, Background colour = 0.5.



The material properties of the objects A, B and C are given as follows:

- Material of surface A: $k_a = 0.2$, $k_d = 0.2$, $k_r = k_s = 0.3$, $k_t = 0.3$, m (shininess) = 2
- Material of surface B: $k_a = 0.2$, $k_d = 0.3$, $k_r = k_s = 0.5$, $k_t = 0$ (surface is opaque)
- Material of surface C: $k_a = 0.2$, $k_d = 0.4$, $k_r = k_s = k_t = 0$ (surface is opaque)

(Note: $\cos(7.5^\circ) = 0.98$, $\cos(15^\circ) = 0.96$, $\cos(30^\circ) = 0.87$, $\cos(35^\circ) = 0.82$, $\cos(45^\circ) = 0.71$, $\cos(60^\circ) = 0.5$.)

d A particular ray tracer supports a number of solid objects. A routine `trace(ray)` returns the list of intersections of the specified ray with the model. Explain how you could extend the ray tracer to handle objects built using Constructive Solid Geometry (CSG).

The four parts carry, respectively, 20%, 20%, 40% and 20% of the marks.

3 Clipping and Containment

a An important test used to determine whether a line segment intersects a polygon is to see whether the end points of the line segment are in the same halfspace created by the plane of the polygon. Use this method to determine whether the line segment joining the point (2,3,6) to the point (1,-5,4) cuts the plane 3x - y + z = 4.

b A polygon face of a convex object has the following four vertex coordinates (1,0,1), (1,3,1), (3,4,0) and (4,0,-0.5). A vertex on an adjacent face of the same object is (3,1,4). Find the inner surface normal of the polygon.

c Use your result in part b to determine whether the point (1,1,2) is on the same side of the polygon face as the vertex on the adjacent face defined in part b.

d Describe an algorithm that will determine whether a point P is contained within a convex polyhedron. Use pseudocode if you wish.

e The same polygon that was defined in part b is now used as a face of a concave object. A line segment goes from point (5,2,2) to (1,0,-2). Determine whether the line segment intersects the polygon.

Hint: You need to find the intersection with the plane of the polygon first, then test to see if the point is contained within the polygon.

The five parts carry equal marks.

4 Viewing Transformations

a A graphics scene is to be transformed so that every point is reflected in the plane $3x + 4z + 3 = 0$. Derive a homogenous transformation that will carry out this reflection.

The transformation can be derived in three steps. First the scene should be transformed such that the plane of reflection lies on one of the planes x=0, y=0 or z=0. Then the reflection should be carried out. Finally the scene is restored to the original coordinate system using the inverse of the first transformation.

b The scene is to be drawn in perspective projection with the viewpoint at the origin and the plane of projection z=2. What homogenous transformation matrix achieves this projection?

c Form a combined transformation matrix from your answers to parts a and b and determine the 2D Cartesian coordinate on the viewplane of homogenous point (0,1,1,1)

The three parts carry, respectively, 60%, 20% and 20% of the marks.

