PRIFYSGOL CYMRU; UNIVERSITY OF WALES

DEGREE EXAMINATIONS JANUARY 2002

SWANSEA

Computer Science

CS 307   Computer Graphics II

Attempt 2 questions out of 3

Time allowed: 2 hours

Students are permitted to use the dictionaries provided by the University through the invigilators

CS_307 Computer Graphics II: Modelling and Rendering

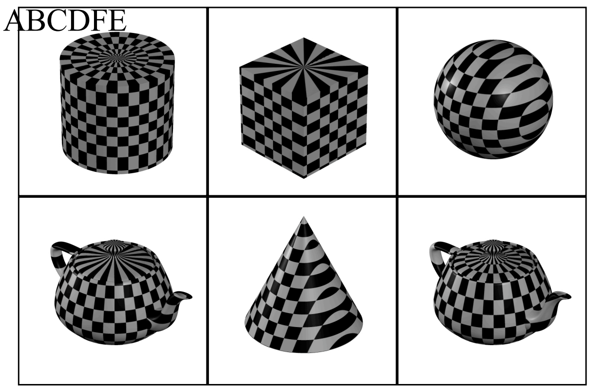
(*Attempt **2** questions out of 3*)

Question 1.

(a) A 3D object is first scaled with scaling factors ($\mathbf{S_x}$, $\mathbf{S_y}$, $\mathbf{S_z}$)=(**2**, **1**, **1**) relative to the origin, and is then rotated by **90** degrees about an axis that is parallel to the z-axis and passes through point (**2**, **2**, **0**). Calculate the composite transformation matrix which performs these two operations.

[5 marks]

(b) A regular chess board pattern is texture-mapped onto the objects as shown on the right using "planar", "cylindrical" and "spherical" mapping methods. For each object, identify the mapping method used.

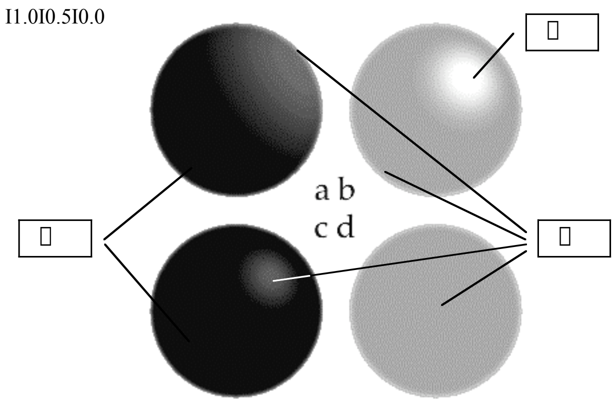


In addition to the basic 2D pattern/image mapping, texture mapping has been generalised to deal with other object attributes or more complex geometrical properties. Briefly describe two such methods, and state the object attributes or geometrical properties concerned.

[7 marks]

(c) Consider the following simplified Phong illumination model for computing the intensity of light reflected from a surface:

$$\mathbf{I} = \mathbf{I_a k_a} + \mathbf{I_p}\left[\mathbf{k_d}(\mathbf{L} \bullet \mathbf{N}) + \mathbf{k_s}(\mathbf{V} \bullet \mathbf{R})^{\mathbf{n}}\right].$$



With the aid of a diagram, explain what directions are represented by vectors **N**, **L**, **V** and **R** respectively.

Consider the scene on the right. It is known that the scene was rendered with $\mathbf{I_a} = \mathbf{I_p} = 1$, and $\mathbf{n} = 12$. It is also known that $\mathbf{k_a}$, $\mathbf{k_d}$ and $\mathbf{k_s}$ for all four objects were set to either 0 or 0.5. For each object, determine the values of $\mathbf{k_a}$, $\mathbf{k_d}$ and $\mathbf{k_s}$.

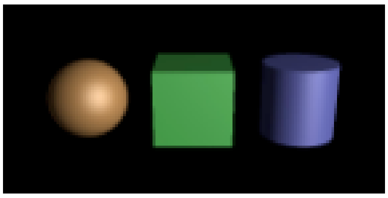
Define the standard distance attenuation function $\mathbf{f}_{att}$, and describe the complete Phong illumination equation by adding $\mathbf{f}_{att}$ to the above simplified illumination model.

With the aid of appropriate equations or/and a diagram, explain why the position of a specular highlight depends on both the position of the light source concerned and that of the view reference point.

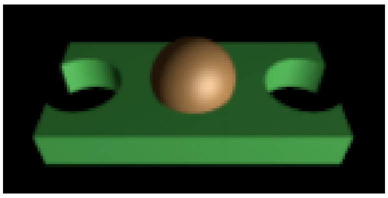
[13 marks]

Question 2.

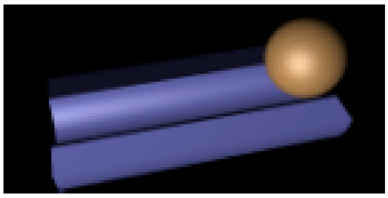
(a) Describe the concept and operations of Constructive Solid Geometry (CSG), and discuss the need for *regularisation*. With the aid of appropriate CSG trees (or CSG terms), describe how you would specify the two composite objects using the three available primitive objects (as shown below). It is necessary to give the precise regularised Boolean set operators used, but not the geometrical transformations involved.



primitives **A**, **B**, **C**



composite object **X**



composite object **Y**

[6 marks]

(b) Consider **n** three dimensional points whose coordinates (x_i, y_i, z_i; i=1,2,...**n**) are given as integer numbers within the range [0, **M**-1]. We would like to draw these points onto an **M**x**M** frame buffer with a *"hidden-point removal algorithm"*. With the aid of a flowchart or pseudo-code, outline the following algorithms:

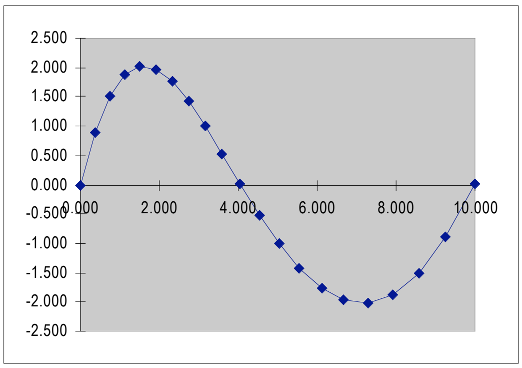
(i) a hidden-point removal algorithm using an image-space method (e.g. the z-buffer method);
(ii) a hidden-point removal algorithm using an object-space method; and
(iii) a hidden-point removal algorithm using a combined image and object-space method.

We assume that no viewing transformation and normalisation is required and parallel projection is used for displaying these points, that is, point (x_i, y_i, z_i) is drawn at pixel (x_i, y_i) in the frame buffer.

[9 marks]

(c) A 2-D Bézier curve is shown below on the right. Which of the following sets of control points might it match? Show how the answer is obtained. (Hint, you may eliminate most cases simply by observation.)

	$P_1(x, y)$	$P_2(x, y)$	$P_3(x, y)$	$P_3(x, y)$
A:	0, 0	5, 7	5, 7	10, 0
B:	0, 0	5, 7	5, -7	10, 0
C:	0, 0	5, -7	5, 7	10, 0
D:	0, 0	2.5, 7	7.5, -7	10, 0
E:	0, 0	2.5, 7	5, -7	10, 0
F:	0, 0	2.5,-7	7.5, 7	10, 0
G:	0, 0	0, 10	10, -5	10, 0



From curves A-G, identify those pairs (of different curves) which may join together such that the first order geometric continuity (G^1) is maintained. For each pair in your answer, indicate clearly the order of the two curves.

If a polyline of 3 points is used to draw curve G, calculate the coordinates of the three points. The Bézier matrix $\mathbf{M_B}$ is shown on the right.

$$\begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

Describe how a Bézier surface patch is defined.

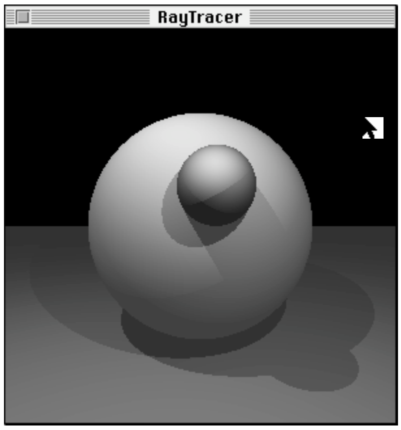
[10 marks]

Question 3.

(a) With the aid of a diagram, show the main functional modules of a graphics pipeline. For each of the following methods, indicate its relevance to the graphical pipeline by associating it to a particular part(s) of the pipeline.

(i) radiosity computation, (ii) viewing transformation,
(iii) Gouraud shading, (iv) parametric surfaces

[4 marks]



(b) The image shown on the right is synthesised using ray tracing. Using this image as an example, and a sketch of the possible scene, explain how shadows are determined in an eye-ray tracing algorithm.

In the context of projection-based rendering (such as Phong shading), explain how shadows are normally determined? Describe one shadow algorithm in detail. (Hint: you may choose the 2-pass object space method, the 2-pass image space method or any other appropriate algorithm.)

[6 marks]

(c) In the context of volume visualisation, consider the marching-cubes algorithm and its 2D version, marching squares.

Outline the main algorithmic steps of the marching squares algorithm for constructing a contour from a grey scale image with a pre-defined threshold value. Given a threshold (iso-value) and a square cornered by four pixels, list all six possible patterns of pixel values in relation to the threshold, and the corresponding intersection(s) between the contour and the square.

What kinds of patterns may lead to some ambiguities in determining intersection(s)? Give one 2D pattern, and one 3D, as examples.

Describe an application of volume visualisation and the nature of its volumetric data.

[7 marks]

(d) With the aid of a diagram if necessary, describe the basic radiosity method, and discuss the relative merits of the radiosity in comparison with the basic eye-ray tracing method. You may find the following equations useful.

$$B_i = E_i + \rho_i \cdot \sum_{1 \le j \le n} B_j \cdot F_{ji} \cdot \frac{A_j}{A_i}$$

$$\begin{bmatrix} 1 - \rho_1 F_{11} & -\rho_1 F_{12} & \cdots & -\rho_1 F_{1n} \\ -\rho_1 F_{21} & 1 - \rho_1 F_{22} & \cdots & -\rho_1 F_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ -\rho_1 F_{n1} & -\rho_1 F_{n2} & \cdots & 1 - \rho_1 F_{nn} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix}$$

[8 marks]