PRIFYSGOL CYMRU; UNIVERSITY OF WALES

DEGREE EXAMINATIONS JANUARY 2003

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

Students are NOT permitted to use calculators

CS_307 Computer Graphics II: Modelling and Rendering

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

Question 1.

(a) An illumination model for computing the intensity of light reflected from a surface is given below:

$$\mathbf{I} = \mathbf{I_a k_a} + \frac{1}{\mathbf{a_0} + \mathbf{a_1 d} + \mathbf{a_2 d^2}} \mathbf{I_p} \left[\mathbf{k_d} \left(\vec{\mathbf{L}} \bullet \vec{\mathbf{N}} \right) + \mathbf{k_s} \left(\vec{\mathbf{V}} \bullet \vec{\mathbf{R}} \right)^{\mathbf{n}} \right].$$

(i) With the aid of a diagram, explain what directions are represented by vectors $\vec{\mathbf{L}}$, $\vec{\mathbf{N}}$, $\vec{\mathbf{V}}$ and $\vec{\mathbf{R}}$ respectively.

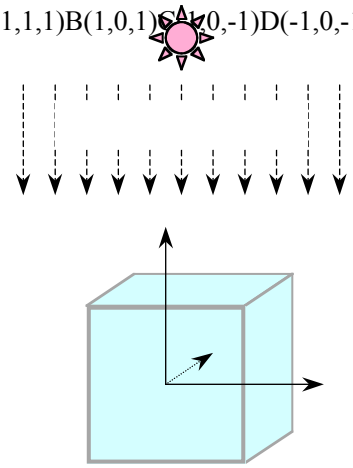
(ii) Describe the effect of varying parameter **n**.

(iii) $\frac{1}{\mathbf{a_0} + \mathbf{a_1 d} + \mathbf{a_2 d^2}}$ is usually replaced by $\min\left[1, \frac{1}{\mathbf{a_0} + \mathbf{a_1 d} + \mathbf{a_2 d^2}}\right]$ in practice. Explain why.

(iv) Using the above illumination model, explain why a specular highlight usually does not stay at the same place on a stationary object in an animation sequence involving camera movement.

[8 marks]

(b) Consider the front face **ABCD** of a cube that is lit by a distance light source as shown on the right. We assume that all points on edges **AB**, **BC**, **CD** and **DA** belong to face **ABCD** only. We also assume that the light intensity of the cube is calculated based on the illumination model given in (a) with



$\mathbf{I_p}$=1, $\mathbf{k_a}$=0, $\mathbf{k_d}$=1, $\mathbf{k_s}$=0, $\mathbf{a_0}$=1, $\mathbf{a_1}$=0, $\mathbf{a_2}$=0,

For each of the following shading methods determine the brightest and darkest parts of face **ABCD**. [Hint: it is not necessary to give exact intensity value, and it is possible that there is more than one brightest (or darkest) point.]

(i) Constant shading, (ii) Gouraud shading, (iii) Phong shading.

[5 marks]

(c) Choose two topics from the following three options. For each chosen topic, describe, with the aid of some diagrams if appropriate, its main technical scope, addressing issues such as main purposes and uses, major concepts and techniques, and relative merits and demerits. It is advised to write 250~400 words for each topic though a longer description will be not be penalised because of its length.

(i) kinematic modelling in computer animation,

(ii) volumetric modelling (including brief discussions on two of such modelling schemes),

(iii) global illumination (including brief discussions on photon ray tracing and radiosity),

[12 marks]

Question 2.

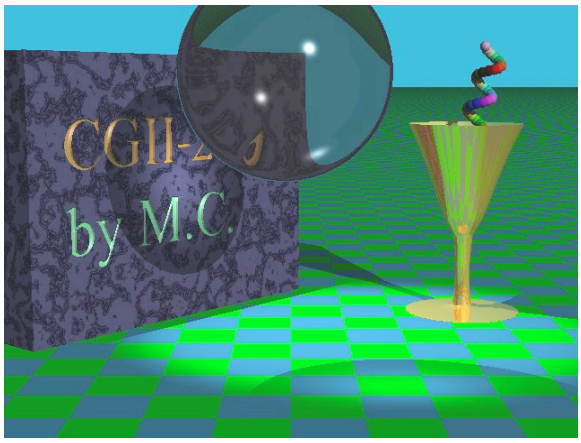
(a) What is meant by the term *vanishing point* in the context of projection? Which type of projection usually features vanishing points? With the aid of a diagram, show an appropriate projection of a cube, which features three vanishing points. With the aid of another diagram, design an object and show an appropriate projection of the object, which features more than three vanishing points.

[6 marks]

(b) A 3D object is first rotated about the z-axis by **90** degrees relative to the origin, and is then scaled with scaling factors $(\mathbf{S_x}, \mathbf{S_y}, \mathbf{S_z})=(\mathbf{1}, \mathbf{2}, \mathbf{2})$ relative to a fixed point $(\mathbf{T_x}, \mathbf{T_y}, \mathbf{T_z})=(\mathbf{0}, \mathbf{1}, \mathbf{5})$. Calculate the composite transformation matrix which performs these two operations.

[5 marks]

(c) The image shown on the right is synthesised using ray tracing.



(i) Describe how would you specify the geometry and surface details of the marble block and the wine goblet.

(ii) Using this image as an example, and a sketch of the possible scene, explain how shadows are determined in an eye-ray tracing algorithm.

(iii) For each the following modifications to the scene specification or rendering conditions, state if it would result in any change in the synthesised image? Briefly explain your answer for each modification. If your answer is "yes", please also describe the likely changes in the resultant image.

(A) Introduce another point light source located behind the marble block.
(B) Changing the refraction index of the wine goblet.
(C) Moving the centre of projection away from the view plane in the opposite direction of the view plane normal.
(D) Introducing *depth cueing*.
(E) Introducing *tree-depth control* by discarding any ray at recursion level 4 or more.
(F) Introduce the *item buffer* algorithm to the rendering process.
(G) Introduce *area sampling* to the rendering process.

(iv) Discuss if the volume ray casting algorithm is suitable for rendering such a scene (in about 150-250 words).

[14 marks]

Question 3.

(a) Give a short description (in about 100-150 words) of each of the following terms.

(i) 3D geometric transformation, (ii) 3D shear transformation,

(iii) viewing transformation.

[6 marks]

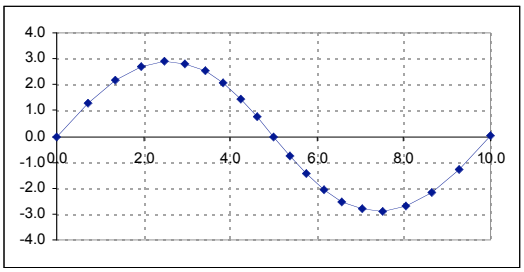
(b) With the aid of pseudo-code or a flow chart, outline the z-buffer algorithm for determining the visibility of a set of triangles in 3D space. Describe how the z-values of points on a triangle are normally calculated.

With the aid of a diagram, describe how the concept of the z-buffer algorithm can be used to determine shadows.

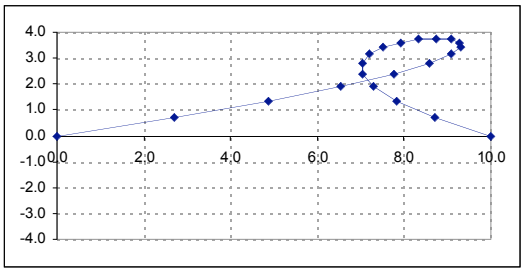
[8 marks]

(c) Consider the following seven sets of control points for cubic 2D Bézier curves.

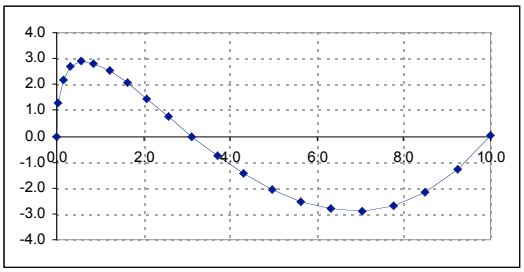
	$P_1(x, y)$	$P_2(x, y)$	$P_3(x, y)$	$P_4(x, y)$
A:	**0, 0**	**5, 10**	**5, 10**	**10, 0**
B:	**0, 0**	**5,10**	**5, -10**	**10, 0**
C:	**0, 0**	**5, -10**	**5, 10**	**10, 0**
D:	**0, 0**	**0,10**	**5,-10**	**10, 0**
E:	**0, 0**	**0,10**	**10,-10**	**10, 0**
F:	**0, 0**	**10,5**	**0,5**	**10, 0**
G:	**0, 0**	**20,5**	**0,5**	**10, 0**



(a)



(b)



(c)

(i) For each curve shown on the right, identify the corresponding set of control points? (Hint, you may eliminate most cases simply by observation.)

(ii) From curves A-E, identify one set of three *different* curves which may join together such that the first order geometric continuity (G^1) is maintained. State the order in which these curves are joined together.

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

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

(iv) Discuss in what ways a cubic Bézier curve differs from a Catmull-Rom spline curve, and in what ways they are similar?

[11 marks]