NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2020-2021

CZ2003 – COMPUTER GRAPHICS AND VISUALISATION

Apr/May 2021 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 pages.
2. Answer **ALL** questions.
3. This is a closed-book examination.
4. All questions carry equal marks.

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1. (a) A plane is determined in the Cartesian coordinate system XYZ by a point with coordinates (6, 5, 4) and a straight line defined by parametric equations
$x = 1 + 3u \quad y = 2 + 3u \quad z = 3 + 3u, \quad u \in$ R.
Define the plane by implicit function $f(x, y, z) = 0$, $x, y, z \in$ R.
(5 marks)

(b) Propose parametric functions $x(u)$, $y(u)$, $u \in [0, 1]$ which will define the curve shown in Figure Q1b so that $x(0) = 0$, $y(0) = 0$.
(8 marks)

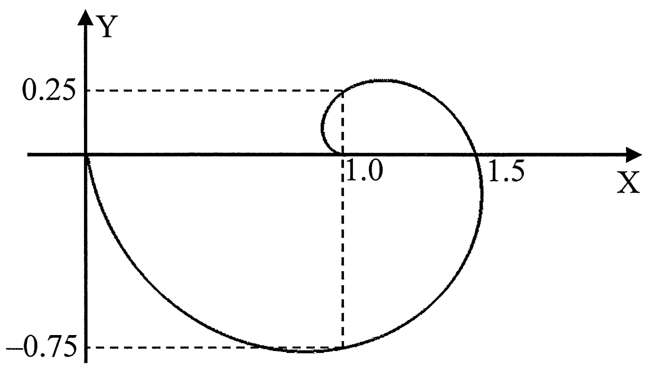

Figure Q1b

Note: Question No. 1 continues on Page 2

(c) Propose parametric functions $x(u, v), y(u, v), z(u, v)$, $u, v \in [0, 1]$ which will define the surface created by $3\pi/2$ rotation about axis Z of the linearly scaled sine curve as shown in Figure Q1c. The rotation of the curve must start on negative axis Y.

(12 marks)

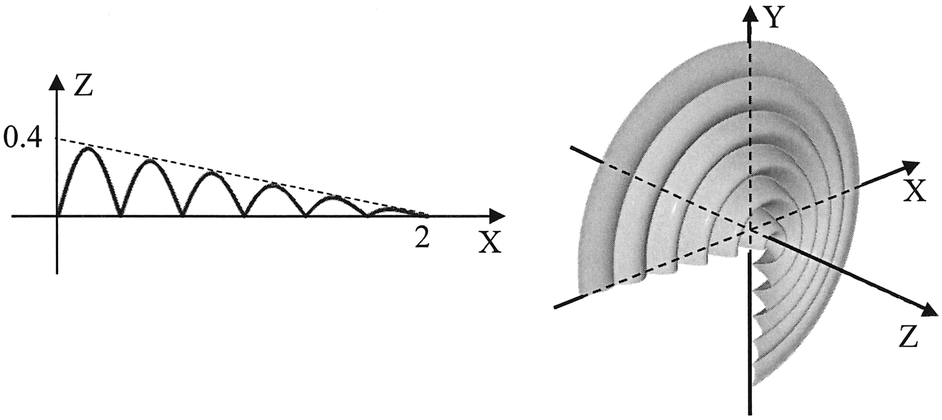

Figure Q1c

2. (a) A straight line is defined in the Cartesian coordinate system XY by an implicit equation $x + 2y - 2 = 0$. Define this straight line in polar coordinates $r\alpha$ by function $r = f(\alpha)$.

(5 marks)

(b) Define by functions $f(x, y) \geq 0$ the object shown in Figure Q2b.

(8 marks)

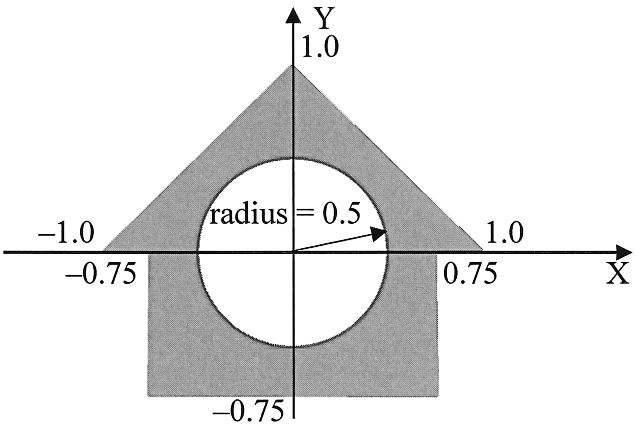

Figure Q2b

Note: Question No. 2 continues on Page 3

(c) With reference to Figure Q2c, propose parametric functions $x\,(u, v, w), y\,(u, v, w), z\,(u, v, w)$, $u, v, w \in [0, 1]$ which will respectively define:

(i) An origin-centred square polygon with the size 2×2 and the sides parallel to coordinates axes X and Z;

(2 marks)

(ii) A solid pyramid formed by connecting the polygon base defined in part (i) with the apex located on axis Y at coordinate 4;

(4 marks)

(iii) A bent solid object formed by counter-clockwise rotation about axis X the polygon defined in part (i) which was offset in negative Z axis direction.

(6 marks)

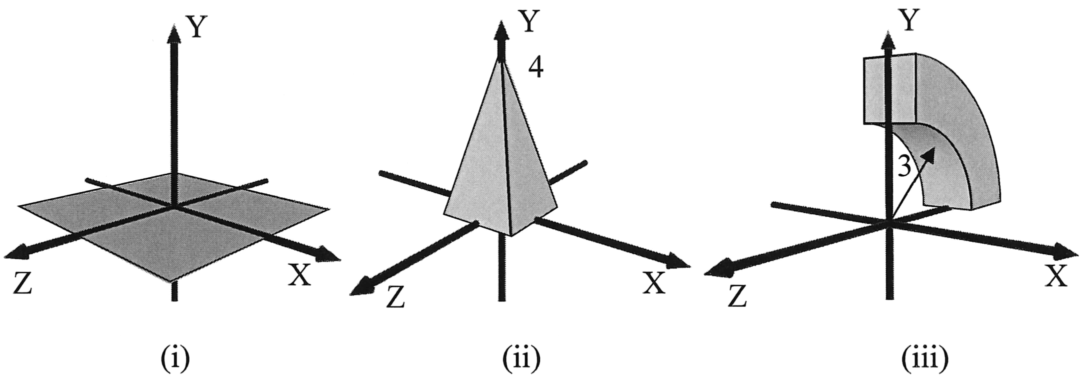

Figure Q2c

3. (a) Suppose that a shiny plane defined by $x - y + z = 1$ is illuminated by the sunlight. Let the lighting direction be (0, 1, 0). If a viewer is at the origin, determine the position on this shiny plane at which the peak of the specular highlight occurs.

(9 marks)

(b) State the difference between bump mapping and displacement mapping.

(3 marks)

Note: Question No. 3 continues on Page 4

(c) Figure Q3c shows 2 spheres generated by the Phong illumination model using the same lighting condition. Which sphere has a larger value of the specular exponent? Justify your answer.

(3 marks)

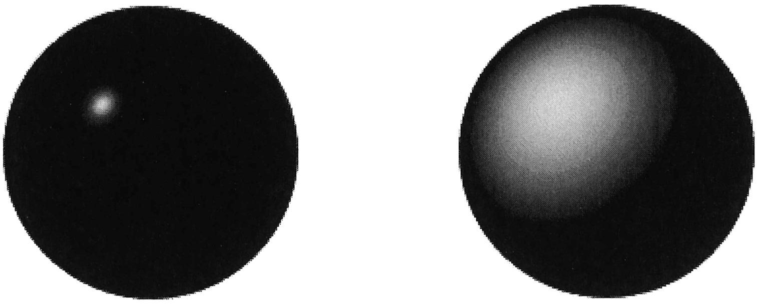

Figure Q3c

(d) Figure Q3d shows a 2D house model. We transform the model by 1 unit distance in the negative x direction, then scale it about the origin by scaling factors 1 (x-direction) and 2 (y-direction), respectively. Finally, we rotate it about a pivot point $(-1, 0)$ by angle 90 degrees clockwise.

(i) Write the composite transformation matrix.

(5 marks)

(ii) Sketch the transformed house model and label the coordinates of all vertices on your sketched figure.

(5 marks)

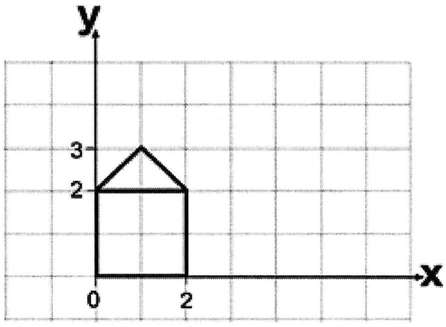

Figure Q3d

4. (a) Propose a mathematical model that implements morphing which transforms a solid ball centered at point (1, 2, 3) with radius 2 into a solid cylinder which is parallel to the Z-axis with radius 2, has center at the point (3, 2, 1) and height of 4. The morphing sequence has 256 frames and involves acceleration. The frame index starts at 1.

(9 marks)

(b) A point light source centered at the point (0, 8) in the coordinate plane XY. A solid disk of radius 1 centered at the point (3, 5) casts a shadow on the X-axis, as shown in Figure Q4b. Let d be the length of the shadow. Compute d. Note that the figure is **not** drawn to scale.

(5 marks)

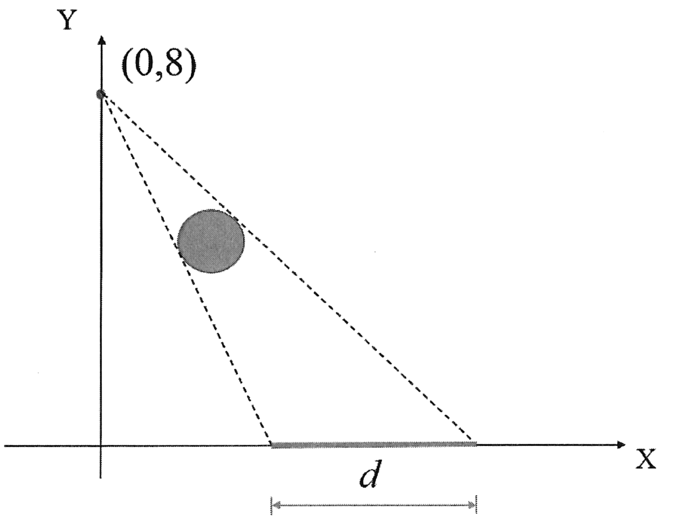

Figure Q4b

(c) Given the following 3D affine transformation matrix:

$$\mathbf{M} = \begin{bmatrix} 3.2 & 2.4 & 0 & 0 \\ -2.4 & 3.2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(i) Describe what transformation the matrix **M** performs when applied to 3D points.

(5 marks)

(ii) Compute the inverse matrix of **M**.

(6 marks)

END OF PAPER

CZ2003 COMPUTER GRAPHICS & VISUALISATION

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.