THIS PAPER IS NOT TO BE REMOVED FROM THE EXAMINATION HALL

UNIVERSITY OF LONDON

CO3355 ZA

BSc EXAMINATION

COMPUTING AND INFORMATION SYSTEMS and CREATIVE COMPUTING

Advanced Graphics and Animation

Wednesday 22 May 2019: 10.00 – 12.15

Time allowed: 2 hours and 15 minutes

DO NOT TURN OVER UNTIL TOLD TO BEGIN

There are **FIVE** questions on this paper. Candidates should answer **THREE** questions. All questions carry equal marks and full marks can be obtained for complete answers to **THREE** questions. The marks for each part of a question are indicated at the end of the part in [.] brackets.

Only your first **THREE** answers, in the order that they appear in your answer book, will be marked.

There are 75 marks available on this paper.

A handheld calculator may be used when answering questions on this paper but it must not be pre-programmed or able to display graphics, text or algebraic equations. The make and type of machine must be stated clearly on the front cover of the answer book.

Question 1 Maths and transformations

(a) Let two points $P_1=(x_1,y_1,z_1)$ and $P_2=(x_2,y_2,z_2)$ in 3D space.

(i) Give an expression for a vector that starts at the origin and ends at P_1.

[2]

(ii) Calculate an expression for a vector that starts at P_1 and ends at P_2.

[2]

(iii) Assuming that the vector calculated in (ii) is nonzero, calculate an expression of a unit vector in the same direction.

[4]

(b) Consider a vector **V**= [3,6]. Calculate its coordinates after a counterclockwise rotation by 0.5π radians around the origin. Show your working.

[4]

(c) Find the angle between each of the following pairs of vectors:

(i) [6,4,2] and [3,2,1]

(ii) [1,2,1] and [1,0,2]

[4]

(d) Consider the following composite 2D operation:

$$\begin{bmatrix}1 & 0 & 1\\ 0 & 1 & 1\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}2 & 0 & 0\\ 0 & 3 & 0\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & -1\\ 0 & 1 & -1\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}x\\ y\\ 1\end{bmatrix}$$

Identify the effect of each of the components. What is the purpose of the combined operation?

[9]

Question 2 Model to screen

(a) Explain what is meant with the term *rasterisation*.

[4]

(b) Given that perspective projection is closer to how our human visual system, as well as cameras, work, why would we ever consider using orthographic projection?

[3]

(c) What is the operation of removing back-facing polygons called? Why is it important?

[2]

(d) Consider a scene that includes three surfaces, *A*, *B* and *C*, as depicted in Figure 1.

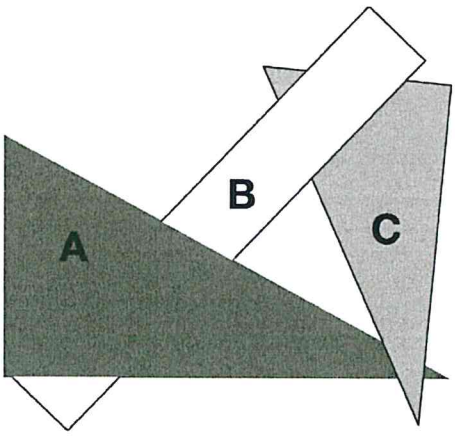

Figure 1 - Rendered surfaces

(i) With reference to the figure, describe the visibility problem in rendering. How does depth buffering solve it?

[4]

(ii) Let the surfaces being rendered in order *A, B, C*. Describe the steps of the z-buffer algorithm.

[4]

(iii) What would the image look like if the surfaces were instead rendered in order *C, A, B*? Justify your answer in a sentence.

[2]

(e) Computer graphics researchers use some standard test models as a basis for evaluating graphics algorithms and techniques. In your opinion, what characteristics constitute a good test model?

[6]

Question 3 Graphics Programming

(a) What is the main difference between a vertex and a fragment shader? Which of the two precedes the other in the graphics pipeline?

[3]

(b) Name three types of operations/effects fragment shaders are suitable for.

[3]

(c) The physics representation of an object is typically different from its graphics one. Why is that so?

[3]

(d) Consider the Processing code that follows:

```
//TO BE REPLACED
  vertex(200, 100);
  vertex(100, 0);
  vertex(300, 0);
  vertex(400, 100);
endShape();
```

Now let the first (commented out) line be replaced by:

(i) `beginShape(TRIANGLES);`
(ii) `beginShape(TRIANGLE_STRIP);`
(iii) `beginShape(TRIANGLE_FAN);`

For each of the three cases draw a diagram of the shape that will be created

[6]

(e) Consider the following Processing code

```
PShader sh;
void setup() {
     size(640, 360, P3D);
     noStroke();
     sh = loadShader("fshader.glsl");
}
void draw() {
     translate(width/2, height/2,0);
     shader(sh);
     sphere(100);
}
```

(i) Describe what it does in one or two sentences.

[2]

(ii) Provide the code of a simple fragment shader `fshader.glsl` that sets the colour of the current fragment to RED.

[3]

(iii) Modify the shader and the Processing code, so that the colour changes periodically and progressively changes from RED to BLACK and vice versa. Let the period of the oscillation be one second.
You can use the Processing function `millis()`:

`public int millis()`
Returns the number of milliseconds (thousandths of a second) since starting the program.

[5]

Question 4 Lighting and Display

(a) What weakness of display devices does *tone mapping* aim to solve? How does it do it?

[6]

(b) Explain what is meant by the term *flat shading*.

[2]

(c) Describe an ideal situation where flat shading would be accurate.

[5]

(d) Using an appropriate diagram, describe the steps involved when calculating the colour of a pixel using Phong shading.

[8]

(e) What problem can emerge when we perform Phong shading to light objects with sharp edges such as a cube? Why?

[4]

Question 5 Texturing

(a) Identify and describe **THREE** coordinate systems used in texture mapping.

[9]

(b) Explain the steps required to carry out texture mapping of an image onto a polygon using a planar map shape.

[8]

(c) Give an example of a scene where you would choose to use *displacement mapping* over *bump mapping*. Justify your answer.

[5]

(d) Why is randomness considered important for achieving realism in texturing? Name two Processing functions used to generate random numbers.

[3]

END OF PAPER