

THIS PAPER IS NOT TO BE REMOVED FROM THE EXAMINATION HALL



**UNIVERSITY  
OF LONDON**

**CO3355 ZB**

**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.

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**Question 1** Maths and transformations.

(a) For each of the following statements say whether they are true or false:

- (i) The components of the sum of two vectors are the sums of corresponding components of the two vectors.
- (ii) Two vectors can only be added if they have the same direction.
- (iii) The dot product of two vectors is another vector of the same dimension.
- (iv) The components of a vector can always be calculated, given its magnitude and direction.

[4]

(b) Consider a vector  $\mathbf{V} = [2, 8]$ . Calculate its coordinates after a clockwise rotation by  $\pi$  radians around the origin. Show your working.

[4]

(c) Consider vectors  $[3, 4, 5]$  and  $[4, 3, 5]$ . Showing your working, calculate:

- (i) the distance between them.

[2]

- (ii) the angle between them.

[2]

(d) "*Homogeneous coordinates are useful because they make all matrix multiplication operations commutative*". State whether this is true and provide a brief explanation.

[4]

(e) Consider the following composite 2D operation:

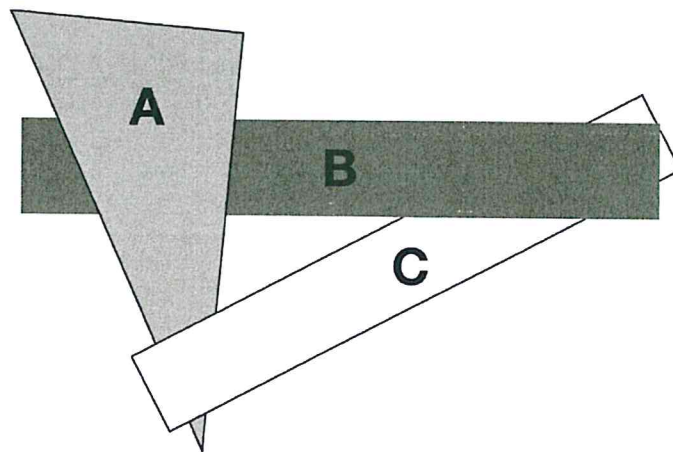
$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & -2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

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 by the term *wireframe*. [4]
- (b) Draw an example of a simple black-and-white 2D image and provide its 6 by 6 raster representation. [2]
- (c) Can you describe a simple scene where using an *object coordinate system* can be useful? [3]
- (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 *B*, *C*, *A*. Describe the steps of the z-buffer algorithm. [4]
- (iii) What would the image look like if the surfaces were instead rendered in order *A*, *C*, *B*? Justify your answer in a sentence. [2]
- (e) Computer graphics researchers use some standard test models as a basis for evaluating and comparing graphics algorithms and techniques. In your opinion, what characteristics constitute a good test model? [6]

### Question 3 Graphics Programming

(a) In the context of physics modelling, shapes can be roughly distinguished in three categories: (i) simple primitives (ii) compound shapes and (iii) meshes. Explain what types of objects are represented by each category. How can you model them in BRLgid?

[6]

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

[3]

(c) Consider the Processing code that follows:

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

(d) 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);
    box(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 BLUE.

[3]

- (iii) Modify the shader and the Processing code, so that the colour changes periodically and progressively changes from BLUE to BLACK and vice versa. Let the period of the oscillation be two seconds.

You can use the Processing function `millis()`:

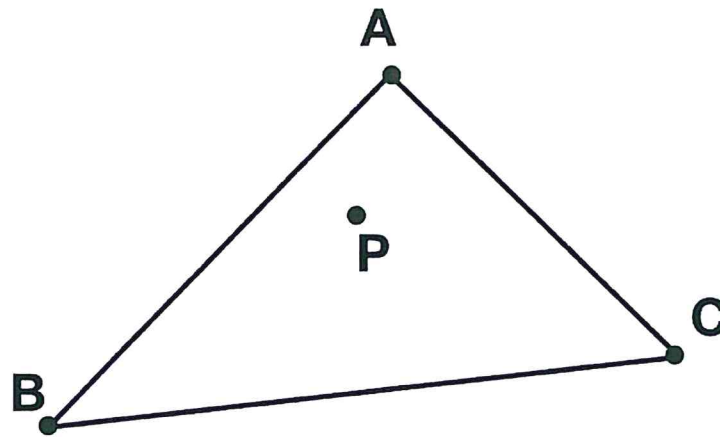
**`public int millis()`**

*Returns the number of milliseconds (thousandths of a second) since starting the program.*

[5]

#### Question 4 Lighting and Display

- (a) Describe the basic process of image-based lighting. [4]
- (b) How is image-based lighting similar to environment mapping? What is their main difference? [2]
- (c) Explain what is meant by the term *flat shading*. [2]
- (d) Describe an ideal situation where flat shading would be accurate. [5]
- (e)
- (i) Figure 2 depicts a particular triangle face of a 3D shape. Describe the steps involved in order to calculate the colour at point *P*, using Gouraud shading.



**Figure 2 – Triangle shading**

- (ii) What problem emerges if light from a narrow directional source hits *P* directly, but does not hit *A*, *B* or *C*? How can it be solved?



### Question 5 Texturing

- (a) What is the difference between texture mapping and procedural texturing?  
[4]
- (b) For the process of texture mapping:
- (i) Identify and describe **THREE** coordinate systems used.  
[9]
  - (ii) Describe the roles of the vertex and the fragment shader.  
[4]
  - (iii) What is a `Sampler2D` variable and how is it used?  
[2]
- (c) Explain the steps involved when a cylinder is used as the map shape in texture mapping.  
[6]

**END OF PAPER**