Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Faculty of Engineering, Mathematics and Science

School of Computer Science & Statistics

Integrated Computer Science Programme **Hilary Term 2016**
Year 4

Computer Graphics

Tuesday 12 January 2016 **Exam Hall** **09.30 – 11.30**

Dr Rachel McDonnell

Instructions to Candidates:

Attempt **four** questions. All questions carry equal marks. Each question is scored out of a total of 25 marks.

You may not start this examination until you are instructed to do so by the invigilator.

Materials Permitted for this examination:

Non-programmable calculators are permitted for this examination – please indicate the make and model of your calculator on each answer book used.

Question 1: Illumination

(a)	"Phong Shading can be implemented in the Vertex Shader of a modern programmable graphics card." Is this statement true or false? Discuss your reasoning.	(5 Marks)
(b)	A student has built a basic backwards (i.e. from-the-eye) Recursive Ray Tracer that works. They are considering adding extra features. Describe each of these features, and what the advantage of each would be (what improvement would they get) in the context of Recursive Ray Tracing. i. More levels of recursion ii. A bounding volume hierarchy iii. Anti-aliasing	(14 Marks)
(c)	In specular illumination, what does $(V.R)^n$ model, where V is the view vector, and R is the reflected vector? Provide a description and diagram. (4 marks) What is *n* known as, and what would the effect of different values of *n* be? (2 marks)	(6 Marks)

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Question 2: Animation

(a)	Sketch a simple hierarchical model of a helicopter. Provide the corresponding scene graph and pseudocode to animate the vertical ascent (take-off) of the helicopter.	(9 Marks)
(b)	You are working on a war scene in a movie with an army of virtual humans, some on foot and some on horse-back. Briefly describe each of the techniques below and what part of the animation they could be used for. 1. Physically-based animation (4 marks) 2. Motion capture (4 marks) 3. Keyframing (4 marks) 4. Inverse Kinematics (4 marks)	(16 Marks)

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Question 3: Linear Algebra and Geometry

(a)	What are homogeneous coordinates and why are they used in computer graphics?	(5 Marks)
(b)	Describe the process for rotation of an object about an arbitrary axis by some angle Θ. Assume the axis is defined by the points P and Q.	(10 Marks)
(c)	Suppose you have an aircraft simulation. You know the aircraft's • world position; • forward vector; • up vector. Write a pseudo-code function to determine if a given world position is ahead or behind, and to the left or the right of the aircraft. You may use a diagram to explain your method.	(10 Marks)

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Question 4: Viewing

(a)	Stereo images are produced by creating two images with the viewer in two slightly different positions. Consider a viewer who is at the origin but whose eyes are separated by Δx units. What are the appropriate viewing specifications to create the two images? Assume the availability of the lookAt function.	(5 Marks)
(b)	Given the image below, provide the modern shader-based OpenGL application code and shaders to show how this image could be created. Assume that we have already loaded a vertex buffer object with the necessary vertex data for a regular teapot object, and have enabled and bound that buffer. Also, assume that you have access to functions to rotate, translate, and do perspective and orthographic projections on 4 x 4 matrices. 	(10 Marks)
(c)	Derive the matrix to represent a perspective transformation of a point in three dimensions to a point on a screen in the plane $z = d$. Assume that the viewer is at the origin.	(10 Marks)

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Question 5: Hardware Pipeline and Shaders

(a)	What is the purpose of using two colour buffers, where one is to draw into while the other is being displayed?	(5 Marks)
(b)	List the principal transformations in a typical 3D graphics pipeline and explain their roles.	(10 Marks)
(c)	Write a vertex shader that, when applied to a sphere model, makes the sphere grow and shrink repeatedly over time. Exact GLSL syntax is not necessary, but specify the inputs needed, the transform applied, and the output of the shader.	(10 Marks)

Question 6: Miscellaneous

(a)	We have used Bezier curves to model a large spaceship. Then we decide to make a minor change at the tip of the ship. What inherent problems of Bezier curves will we run into? What alternate representations can reduce this problem? Explain briefly.	(5 Marks)
(b)	Explain how a depth buffer (z-buffer) works.	(5 Marks)
(c)	Given a ray with origin (0, 0, 0) which travels in the direction (0.31, 0.1, 0.95), and a sphere with radius 20cm and center (38, 12, 130), work out if the ray intersects the sphere and, if so, the point of intersection. Show how you derived the discriminant clearly.	(15 marks)

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