# UNIVERSITY OF DUBLIN

## TRINITY COLLEGE

### Faculty of Engineering, Mathematics and Science

School of Computer Science and Statistics

**B.A.I. Engineering**
**B.A. (Mod.) Business & Computing**

**Trinity Term 2013**

## CS4D3 – Computer Graphics

**Friday 3d May 2013** **Sports Centre(455)** **14:00-16:00**

**Dr. Rachel McDonnell**

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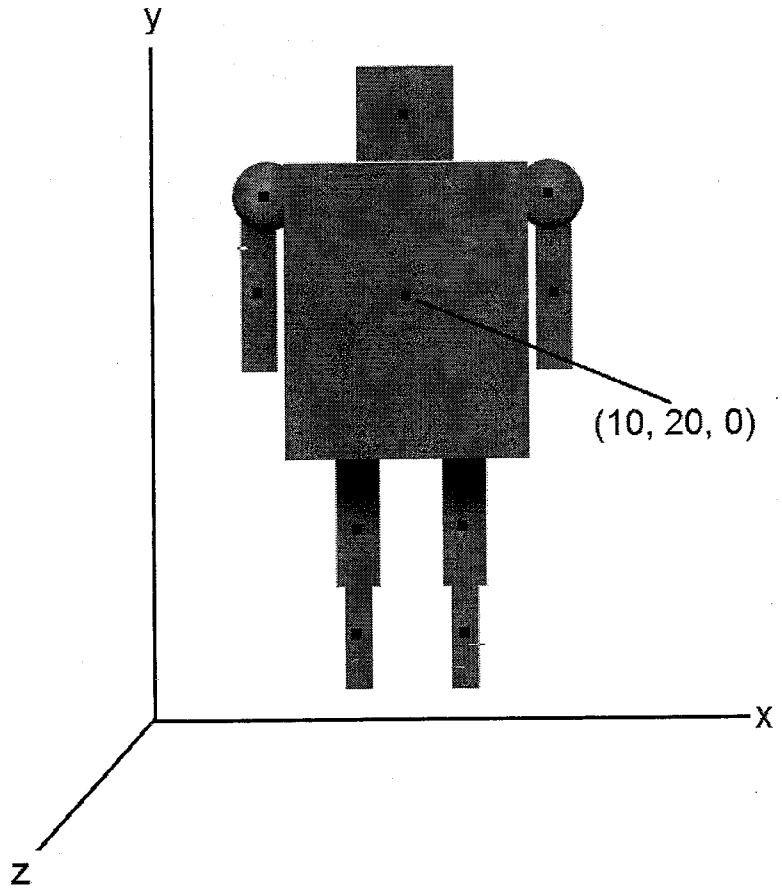
### Instructions to Candidates:

Answer any FIVE questions – 20 marks each.
All questions carry equal marks.

Please use a **separate answer book** for each question.
**The entire question paper must be handed in at the end of the examination.**

**Question 1: Geometric Transformations**

| | | |
|---|---|---|
| |  | |
| (a) | Roughly estimate the positions of the various joints depicted in the hierarchy above and provide the OpenGL (or similar Graphics API) code necessary to create this object. | (6 marks) |
| (b) | How would you widen the torso (biggest block) by 2 units? | (1 marks) |
| (c) | Describe how to bend the arms towards the camera by 45 degrees (using a Right handed system). | (2 marks) |
| (d) | Describe how to add two fingers to one of the arms in the object. The fingers should be linked appropriately to the hierarchy, and should contain two segments each. | (4 marks) |
| (e) | Provide OpenGL code to create an animation loop during which the head can nod and shake (as if saying "no" or "yes"). | (7 marks) |

**Question 2: Shading**

| | | |
|---|---|---|
| (a) | Consider this sequence of calls:<br>`glColor3f(0.0,1.0,0.0);`<br>`glColor3f(1.0,0.0,0.0);`<br>`glVertex3f(1.0,1.0,1.0);`<br>`glVertex3f(2.0,2.0,2.0);`<br>What colour is the vertex (1.0,1.0,1.0)? What colour is the vertex (2.0,2.0,2.0)? | (2 Marks) |
| (b) | What is the purpose of using two colour buffers, where one is to draw into while the other is being displayed? | (4 Marks) |
| (c) | State the equation for the full Phong Illumination model and explain each of the terms. Mention a technique that can be used to accelerate the evaluation of the Phong Illumination Model. | (14 Marks) |

**Question 3: Illumination**

| | | |
|---|---|---|
| (a) | What factors determine the colour of an object at any given point (with respect to illumination models in 3D computer graphics)? | (3 Marks) |
| (b) | Explain the difference between local and global illumination of a point. | (2 Marks) |
| (c) | Explain each of the following with respect to illumination models (using diagrams and equations where appropriate):<br>i. The Inverse Square Law<br>ii. The Cosine Rule<br>iii. BRDF (include examples) | (15 Marks) |

**Question 4: Linear Algebra**

| Given vectors $\boldsymbol{u}$ = (4, 11, 23) and $\boldsymbol{t}$ = (3, -2, 7), and point P = (3, -2, 5) | | |
|---|---|---|
| (a) | Find the magnitude of the vector $\boldsymbol{u}$ and normalize it. | (2 Marks) |
| (b) | Find the dot product of $\boldsymbol{u}$ and $\boldsymbol{t}$ | (2 Marks) |
| (c) | Find a vector $\boldsymbol{v}$ that is perpendicular to the plane defined by $\boldsymbol{u}$ and $\boldsymbol{t}$, using a right-handed coordinate system. | (5 Marks) |
| (d) | Determine whether the point P is on the same side of this plane as indicated by the positive direction of vector $\boldsymbol{v}$ | (5 Marks) |
| (e) | Find a new vector $\boldsymbol{w}$ that is mutually orthogonal to $\boldsymbol{u}$ and $\boldsymbol{v}$, and normalise all three vectors | (6 Marks) |

**Question 5: Viewing**

| | | |
|---|---|---|
| (a) | Explain each of the following terms:<br>i. View frustrum<br>ii. Isometric projection<br>iii. Clipping<br>iv. Axonometric projection | (8 Marks) |
| (b) | What is the difference between parallel and perspective projections? For both projection types, describe an application in which it would be preferable. | (4 Marks) |
| (c) | Describe the process for transforming a point using a perspective projection. Use diagrams and equations where appropriate. | (8 Marks) |

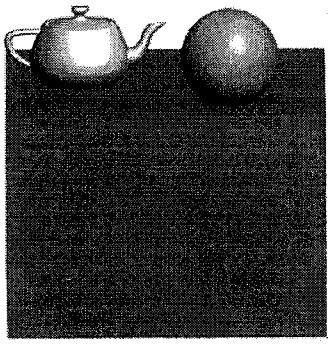
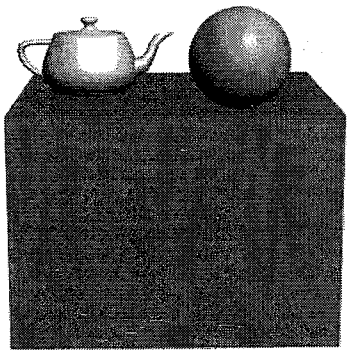
**Question 6: Curves**

| | | |
|---|---|---|
| (a) | Draw a curve made from two piecewise Bezier curves that is C0 continuous but not C1 continuous, and discuss the differences. | (2 Marks) |
| (b) | Describe Hermite Curves and how they are derived. Discuss the main drawback of the Hermite form and how the Bezier form overcomes this. | (9 Marks) |
| (c) | Explain each of the following in the context of Parametric Cubic curves, giving example matrices where appropriate.<br>i. Basis matrix<br>ii. Geometry matrix<br>iii. Blending functions | (9 Marks) |

**Question 7: Geometric Transformations**

| | | |
|---|---|---|
| (a) | i. Sketch the result of applying the following OpenGL transformations, assuming that the box object is at the origin with the identity matrix applied:<br><br>drawBox();<br>glTranslatef(-1, 3, 0);<br>glPushMatrix();<br>glRotatef(90, 0, 0, 1);<br>glTranslatef(1, 0, 0);<br>glPopMatrix();<br>glRotatef(90, 0, 0, 1);<br>glTranslatef(1, 0 , 0);<br><br>ii. Give the parameters θ ,x ,y required for the following OpenGL calls so that they accomplish the same transformation as above:<br><br>drawBox();<br>glRotatef(θ ,0, 0, -1);<br>glTranslatef(x, y, 0); | (8 Marks) |
| (b) | In the various steps in the fixed function OpenGL geometry pipeline, transformations occur between different coordinate systems. Illustrate the pipeline with an image and discuss, in detail, the different stages of vertex transformation. | (12 Marks) |

**Question 8: Miscellaneous**

| | | |
|---|---|---|
| (a) | Name three sources of 3D data. | (3 Marks) |
| (b) | Explain the function of the MODELVIEW matrix and CTM in OpenGL. | (4 Marks) |
| (c) | Give rough estimates of the viewing parameters that are being used to create the two images below and provide the OpenGL (or similar API) code that could be used to set up and render the scene and both views.<br>(i)  <br>(ii)  | (13 Marks) |