Student ID: _____

# UNIVERSITY OF OTAGO EXAMINATIONS 2013

## COMPUTER SCIENCE

**Paper COSC342**

**COMPUTER GRAPHICS**

**Semester 1**

**(TIME ALLOWED: THREE HOURS)**

This examination comprises 5 pages including this cover page.

Candidates should answer questions as follows:

Candidates must answer **all** of the 15 questions within this examination.

Questions are worth various marks and are shown thus: (5)

The total number of marks for this exam is 60.

You should keep your answers short.

In general, if there are two points for an answer, you should have two things to say.

Use of calculators

No calculators are permitted.

Other instructions

At the end of the exam, hand in the entire exam paper attached to the answer book(s).

**TURN OVER**

1. How do the components of a pixel on an LCD display work together to cause that pixel to be lit up or not? Include a diagram that illustrates the role of each of these main components. How might wearing polarising sunglasses affect users' visibility of LCD screens? (6)

2. Describe one advantage and one disadvantage of OLED displays compared to LCD displays. (2)

3. LCD displays often use sub-pixels that have three different colours. Indicate the approximate shape of their colour gamut on the CIE chromaticity diagram. Some OLED displays add an extra white sub-pixel. Indicate how having four sub-pixel colours will change the shape of the colour gamut. (3)

4. (a) Illustrate the main parts of a black and white laser printer, and describe how they interact to produce a page of printed material. (4)

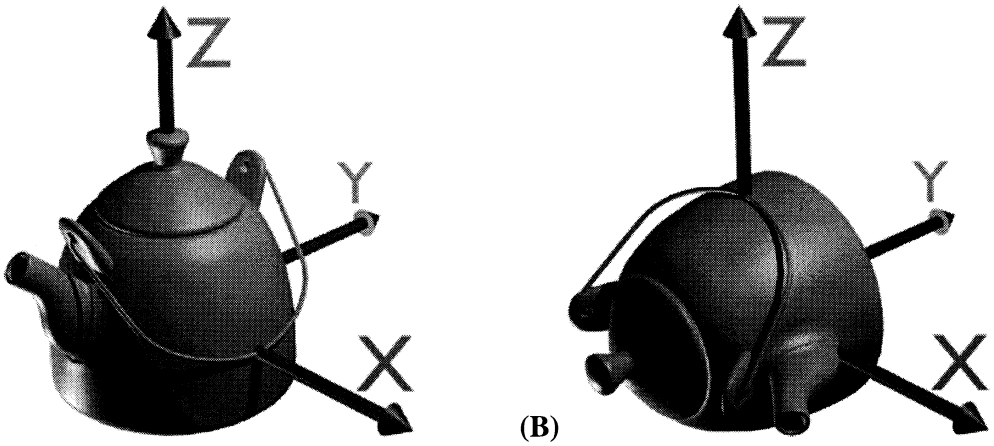
   (b) To print food colouring into the surface of cake, indicate whether it is more likely that a laser printer or an inkjet printer can be used, and explain why. (2)

5. A form of Bresenham's line drawing algorithm is reproduced below:

```
d = rx / 2;
incr = rx - ry;
for (i = 1; i <= rx; i++)
{   x = x - 1;
    if (d < ry)
    {   y = y + 1;
        d = d + incr;
    } else
        d = d - ry;
    pixel[x][y] = colour;
}
```

Explain the role of `rx` and `ry`. If `x` and `y` are initialised to 0, `rx` is set to 4, and `ry` is set to 2, illustrate approximately on the $XY$ plane where the resulting line would be drawn. What happens if `rx` is instead set to 2, and `ry` is set to 4? (4)

6. A geometric approximation of a sphere can be built using a mesh of 80 identical triangles. However, the edges between the triangles may be visible as sharp changes in brightness. What technique can we use to make the surface of this triangle mesh look smooth? Describe two situations in which it will still be obvious that the underlying geometry is not smooth. (3)




**(A)** **(B)**

7. The figure, above, shows a teapot in two different axis-aligned orientations. The $X$, $Y$ and $Z$ axes of a right-handed coordinate system are shown.

   (a) Describe the operations necessary to rotate the teapot from the position shown in **A** to the position shown in **B**. No shift is necessary. Just describe the rotations. (2)

   (b) Write down the matrices to represent these rotations. (2)

   (c) Multiply these matrices in the correct order to create the single matrix that performs this transformation. (2)

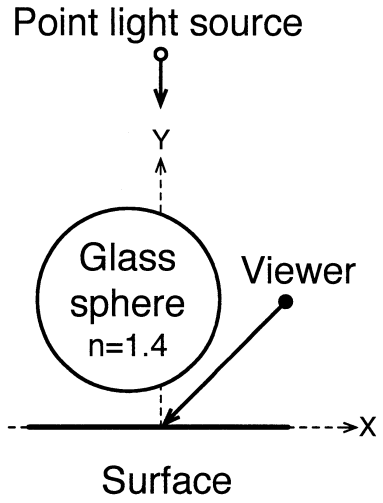
8. Cleary's algorithm is a method for quickly determining the next cell to enter when tracing a ray through a scene stored using uniform spatial subdivision. Explain briefly how the algorithm works. You may explain a two dimensional version of the algorithm. (2)

9. (a) Show in homogeneous coordinate form, the 3D point $\mathbf{p}$ with $x = 2$, $y = 1$ and $z = 2$. (1)

(b) What is the purpose of the following transformation matrix $M$? (1)

$$M = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

(c) Show how the matrix $M$ can be applied to $\mathbf{p}$, and give the result of this transformation. Show how to interpret your result as a 3D coordinate, and describe what you would expect to happen to the result if the z-coordinate of $\mathbf{p}$ is increased. (4)




10. Assume that the diagram above represents a 3D scene, with the $Z$ axis positioned to make a right-handed coordinate system. The centre of the light source, the viewer and the sphere are all positioned on the $XY$ plane.

We are interested in the illumination at the point on the flat surface at the origin, as viewed from the position indicated by 'Viewer' on the figure. The point light source directing light down the $Y$ axis is the only light source in the scene. There is no ambient illumination.

A glass sphere, with refractive index $n = 1.4$ obstructs the path between the light source and the point on the surface at the origin.

(a) Using raytracing with only local illumination models, describe the illumination of the point on the surface at the origin, and why this is the case. (2)

(b) Name a global illumination model that can create a more realistic illumination, and briefly describe how it does so. (2)

11. Explain the role of each of the terms within the Lambertian diffuse illumination component of a greyscale local illumination model: $k_d(\hat{\mathbf{n}} \cdot \hat{\ell})$. How does the amount of surface illumination seen by a viewer depend on that viewer's position? (4)

12. Consider a flat triangle in a 3D space with vertices (2,0,0), (0,2,0) and (0,0,0).

    (a) Giving your answer as a vector, and choosing the direction with positive vector components, indicate the direction of the normal to the surface of this triangle. (1)

    (b) If a point light source is at $\boldsymbol{\ell}$ = (0,0,4), calculate $\hat{\boldsymbol{\ell}} \cdot \hat{\mathbf{n}}$ for the point on the triangle at (0,0,0), showing your working. (Remember that a 'hat' over a vector means that it is a unit vector.) (2)

    (c) Give a different position for $\boldsymbol{\ell}$ that produces the minimum possible illumination of the triangle at (0,0,0). (1)

13. Consider a white 3D triangle that has been transformed onto screen pixels (0,0), (2,0) and (0,2), where the illumination for these vertices, in order, is 100%, 0% and 0%.

    (a) Describe how a scan-line approach using Gouraud shading will determine the pixel colours for the points with y=0 on screen, and what the pixel colours are. (2)

    (b) Describe a relationship between Bresenham's algorithm for drawing lines, and the process used to find pixel colours in Gouraud shading. (2)

14. Describe how raytracing can model motion blur using supersampling of viewplane pixels. If two primary rays were used per viewplane pixel, what would an object look like as it moved across the view? (3)

15. Consider a flat, rectangular texture that will be mapped onto the colour of the pixels of a surface projected onto the screen.

    (a) Describe the usual role of $u$ and $v$ coordinates. (1)

    (b) Briefly describe the effect of under-sampling a texture, and the effect of oversampling a texture. (2)