UNIVERSITY OF OTAGO EXAMINATIONS 2014

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.

Candidates are permitted copies of:

Nil.

TURN OVER

1. Illustrate the role of the main components within an LCD display that together determine whether a pixel is lit up or not. Include both a diagram and some explanatory text in your answer. How would the behaviour of the display change if one of the display's polarising filters was rotated by 90 degrees? (6)

2. Explain the difference in power consumption that occurs between showing a black screen and a white screen for:

   (a) an LCD display (1)

   (b) an OLED display (1)

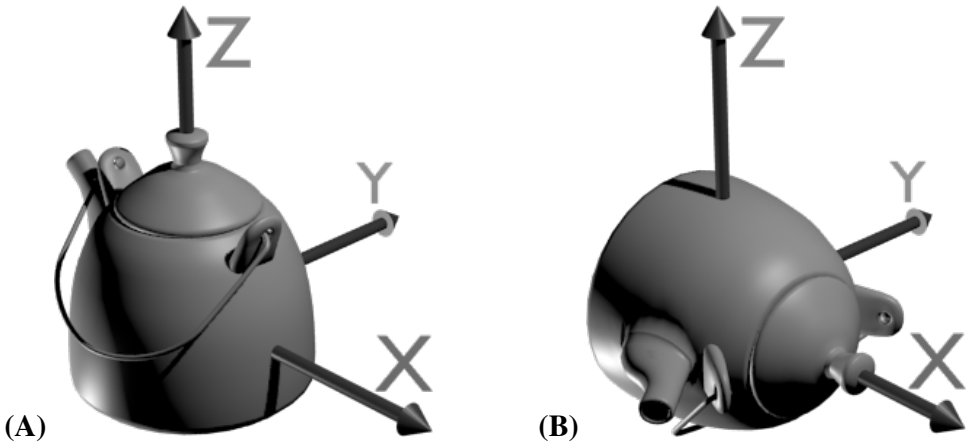
3. Illustrate the main steps in the process of an inkjet printer creating a dot on a page of printed material. (4)

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

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

   Explain the role of `rx` and `ry`. If `x` and `y` are initialised to 0, `rx` is set to 2, and `ry` is set to 4, illustrate approximately on the XY plane where the resulting line would be drawn. To draw a line that progresses in the opposite X direction, what in the algorithm needs to be changed? (4)

5. When raytracing a triangle with 3D vertices $\mathbf{p}_1$, $\mathbf{p}_2$, and $\mathbf{p}_3$, outline how to determine whether the primary ray hits the triangle. (3)



6. 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)

7. Bounding volumes can increase the efficiency of a ray tracer rendering a scene.

   (a) Briefly explain what provides this additional efficiency. (1)

   (b) Describe a situation in which the additional cost of using a bounding volume would outweigh its benefit. (1)

8. (a) Show in homogeneous coordinate form, the 3D point $\mathbf{p}$ with $x = 4$, $y = 2$ and $z = 1$. (1)

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

$$M = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

   (c) Show how the matrix M can be applied to $\mathbf{p}$, and give the result of this transformation, interpreting your result as a 3D coordinate. (3)

   (d) Write down the inverse transformation, M^{-1}. (1)

9. Although a Whitted ray-tracer can allow the viewer to see an appropriately refracted scene through a glass-like object, it cannot render effects of light sources passing through glass-like objects.

   (a) Why is the Whitted ray-tracer unable to do so? (3)

   (b) What is a technique that *can* model such effects, and how does it work? (3)

10. Explain the role of each of the terms within the Phong (specular) illumination component of a greyscale local illumination model: $k_s(\hat{\mathbf{e}} \cdot \hat{\mathbf{r}})^n$. (4)

11. Consider a sphere with radius 2, centred on the origin.

   (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 sphere at the point (0,2,0). (1)

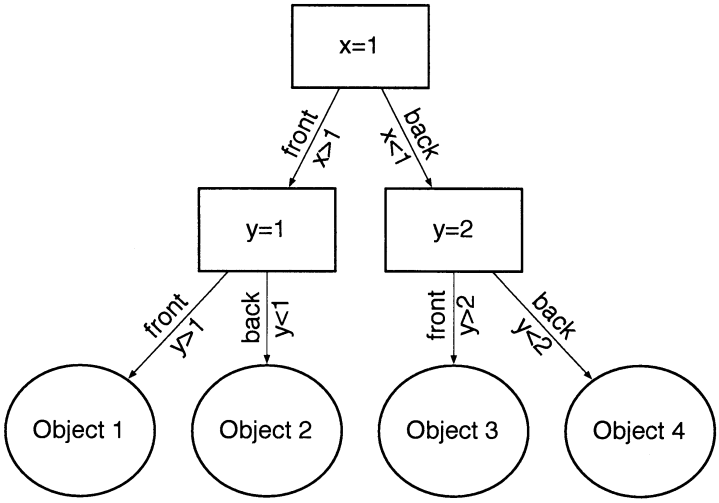
   (b) Consider a point light source at position (4,2,0), and Lambertian diffuse illumination. Calculate $\hat{\boldsymbol{\ell}} \cdot \hat{\mathbf{n}}$ for the point on the sphere at (0,2,0), showing your working. (Remember that a 'hat' over a vector means that it is a unit vector.) (2)

12. Consider ray tracing a scene in which the 'camera' looks off to the horizon, and where the 'ground' is an infinite plane that contains a regular, black and white, checkerboard texture (i.e. if you were to look straight down at the 'ground' from above, you would see repeating black and white squares). If there is no supersampling of rays, and no other form of antialiasing, what will happen to the pixel colours near the horizon? How can the appearance be improved? (3)

13. Consider a 3D triangle that will be drawn into a Z-buffer, that has been transformed onto screen pixels (0,0), (2,0) and (0,2), and has depths 100, 200 and 200 for the points, respectively, where smaller depth values are closer to the viewer.

   (a) Describe the scan-line approach to drawing this triangle into the Z-buffer. (3)

   (b) What is the depth of the pixel at (1,0)? (1)



14. The figure above shows a (3D) Binary Space Partition (BSP) tree. The cutting planes are indicated in the rectangular interior nodes, and four objects are shown at the leaves.

    (a) Ignoring the Z axis, sketch a valid arrangement of the four objects on the XY plane, and the BSP splitting planes. (4)

    (b) BSP trees can ensure that the Painter's Algorithm produces a valid scene from any viewpoint. Consider a viewer at position (2,0,0). Which of the front or back subtree of the root of the BSP tree should be visited first, and why? (Note that the viewer's orientation is not given, because this information is not needed.) (1)

15. Shining white light through a glass prism separates it into a colour spectrum. Most basic ray tracers model colour using red, green and blue channels, where white is a combination of all three channels. If we modelled white light as a combination of red, green and blue photons, and applied photon mapping through a model of a glass prism, what would the resulting colour spectrum look like? How can we produce a realistic spectrum? (2)

END