09h00–12h00	11 JUNE, 2018	MSL111	EXAMS OFFICE USE ONLY

University of the Witwatersrand, Johannesburg

Course or topic No(s)	COMS 3006
Course or topic name(s) Paper Number & title	Computer Graphics & Visualization
Examination to be held during the month(s) of	JUNE
Year of study	3
Degrees/Diplomas for which this course is prescribed	BSc Undergraduate
Faculties presenting candidates	Science
Internal examiner(s)	Dr. Richard Klein
External examiner(s)	Prof. Stefan Gruner (UP)
Special materials	
Time allowance	180 MINUTES
Instructions to candidates	• This is a closed book test. • Answer all the questions in the answer book. • Answer in pen. • Calculators are permitted.

FINAL WRITTEN EXAM

DATE: 11 JUNE, 2018 **TIME:** 09h00–12h00

ASSESSOR(S): Dr. Richard Klein
INTERNAL MODERATOR:
EXTERNAL MODERATOR: Prof. Stefan Gruner (UP)
DURATION - 180 MINUTES **MARKS -** 90
NUMBER OF PAGES: 5 PAGES INCLUDING FRONT PAGE

SURNAME AND INITIALS: _____

STUDENT NUMBER: _____

CONTACT NUMBER: _____

INSTRUCTIONS
- This is a closed book test.
- Answer all the questions in the answer book.
- Answer in pen.
- Calculators are permitted.

1. Answer the following short questions:
   (a) What do we mean by the render-to-texture technique? (2)
   (b) What is meant by a renderbuffer in WebGL? (2)
   (c) What are object coordinates? (1)
   (d) Which transform converts between Object Coordinates and World Coordinates? (1)
   (e) What type of transformation guarantees that parallel lines remain parallel? (1)
   (f) Convert the $[0, 14, 7, 3.5]$ from homogeneous coordinates to cartesian coordinates. (1)
   (g) What is a Bezier curve and how is its shape specified? (2)
   (h) What is an indexed face set? (2)

   Total for Question 1: 12

2. A key component of modern graphics is shaders. Describe what these shaders are, their value, and how the different shader types relate to one another. A diagram can go a long way towards a good answer. (8)

   Total for Question 2: 8

3. Describe how attribute, uniform and varying variables in shaders differ from each other. (7)

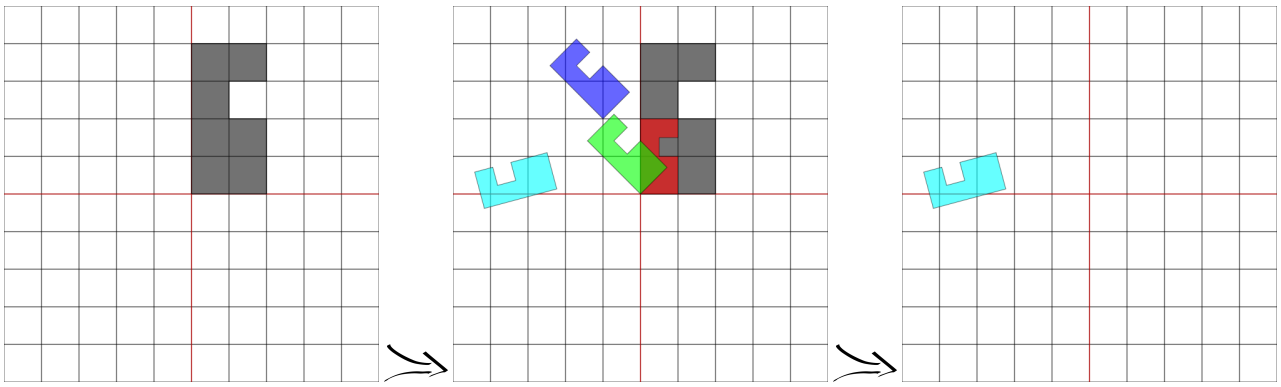
   Total for Question 3: 7

4. An equation for alpha blending for a pixel c is given by $c = \alpha f + (1 - \alpha)b$ where α is the alpha value, f is the foreground colour and b is the background colour. Calculate what the 8-bit RGB colour c would be after alpha blending occurred with an alpha value of 0.3, the foreground colour is (255,128,100) and the background colour is (0,100,100). (3)

   Total for Question 4: 3

5. Given the image on the left. Assuming that the following modelling transformations were applied to arrive at the image on the right.
   (a) Provide the transformation matrices for each modelling step as well as the model transformation M. (7)
   (b) Use the model transform M to calculate where the point P' would end up given $P = (0.0, 0.0)$. (7)

   1. S1: First scale the object by 0.5, 0.5, then
   2. R1: Rotate by 45 degrees, then
   3. T1: Translate by 1 unit to the left, 2 units upwards, then
   4. S2: Rotate by 60 degrees.



Total for Question 5: 14

6. Given a material with ambient, diffuse, specular, and emission colours of the material with RGB components (14)

$$(m_{a,r}, m_{a,g}, m_{a,b}) = (0.0, 0.0, 0.0)$$
$$(m_{d,r}, m_{d,g}, m_{d,b}) = (0.0, 0.5, 0.5)$$
$$(m_{s,r}, m_{s,g}, m_{s,b}) = (0.5, 0.5, 0.5)$$
$$(m_{e,r}, m_{e,g}, m_{e,b}) = (0.0, 0.0, 0.0)$$

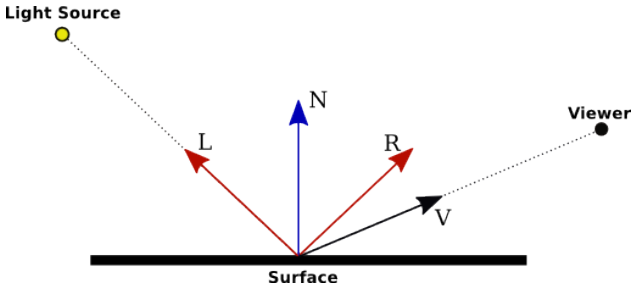
The OpenGL lighting equation for a colour where we have only one light is given by:

$$i = m_e + g_a m_a + l_a m_a + I_{[L \cdot N > 0]} \left(l_d m_d (L \cdot N) + l_s m_s \max(0, V \cdot R)^h \right)$$

where ambient, diffuse, and specular light colour components are

$$(l_{a,r}, l_{a,g}, l_{a,b}) = (1.0, 1.0, 1.0)$$
$$(l_{d,r}, l_{d,g}, l_{d,b}) = (0.5, 0.5, 0.0)$$
$$(l_{s,r}, l_{s,g}, l_{s,b}) = (0.5, 0.8, 0.5)$$

The global ambient light is given by $(g_{a,r}, g_{a,g}, g_{a,b}) = (0.0, 0.0, 0.0)$ and the highlight or shininess by $h = 0.25$. The light is at position $(-5.0, 0.0, 0.0)$. The vectors N, R and V are as in the following diagram. $I_{[\cdot]}$ is the indicator function and has a value of 1 when the argument is true otherwise it is 0.



Consider a point $P = (-5.000, 2.000, 0.000)$ in eye coordinates on the surface with normal, $N = (0.707, -0.707, 0.000)$. Recall that $R = 2 \times (N \cdot L) \times N - L$. Calculate L, R, and V. Calculate the intensity i of the **green** component at P. Show all your working.

Total for Question 6: 14

7. How would you go about adding shadows to your scene if you had to build it from scratch? (5)

Total for Question 7: 5

8. What would be the resultant transformation matrix contained in modelview after the following code snipit has run. Show the individual transformations as well as the final one. (8)

```
var matrixStack = [];
modelview = mat4.create();
mat4.identity( modelview );

mat4.translate( modelview, modelview, [2.0,1.0,0.0] );
mat4.scale( modelview, modelview, [-1.0,2.0,1.0] );

matrixStack.push( mat4.clone(modelview) );
mat4.rotateX( modelview, modelview, Math.PI );

matrixStack.push( mat4.clone(modelview) );
mat4.rotateZ( modelview, modelview, Math.PI );
modelview = matrixStack.pop();
mat4.translate( modelview, modelview, [0.0,0.0,5.0] );
```

Total for Question 8: 8

9. Describe the difference between per-pixel and per-vertex lighting with respect to shaders. Which of these solutions is better and why? (6)

Total for Question 9: 6

10. Draw two diagrams showing the difference between perspective projection and orthographic projection with respect to their various parameters. Give an example of where each might be used in a 3D game. (8)

Total for Question 10: 8

11. Display Lists were originally part of OpenGL 1.0 and were used as a way to improve rendering performance. Later, in OpenGL 1.5, Vertex Buffer Objects were introduced to improve this performance. What are Display Lists and how did they improve performance over the typical OpenGL 1.0 rendering process? What are Vertex Buffer Objects and how did they improve performance over Display Lists? (5)