

Paper CODE	EXAMINER	DEPARTMENT	TEL
CPT205		Computing	

1st SEMESTER 2023/24 FINAL EXAMINATION

Undergraduate – Year 3

COMPUTER GRAPHICS

TIME ALLOWED: 2 Hours

INSTRUCTIONS TO CANDIDATES

- 1. This is a closed-book examination, which is to be written without books or notes.**
- 2. Total marks available are 100.**
- 3. Answer ALL questions in this examination. It is not necessary to copy the questions into the answer booklet.**
- 4. Answers should be written in the answer booklet(s) provided. There is NO penalty for providing a wrong answer.**
- 5. Only solutions in English are accepted.**
- 6. All materials must be returned to the exam invigilator upon completion of the exam. Failure to do so will be deemed academic misconduct and will be dealt with accordingly.**

Question 1. Fundamentals

[Total 20 marks]

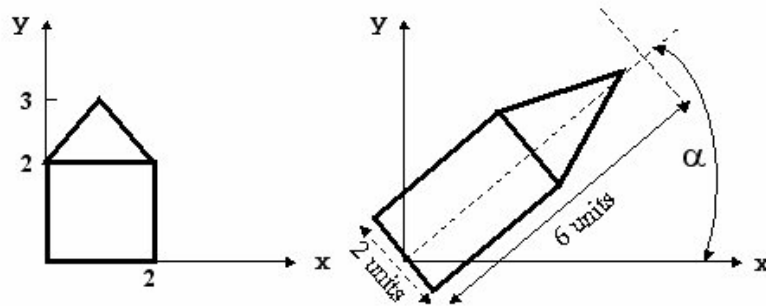
- 1.1. Briefly describe OpenGL. [2 marks]
- 1.2. List 4 items of hardware included in a typical graphics system. [2 marks]
- 1.3. For a screen with a resolution of 1920*1080 pixels what size of a framebuffer is needed for storing 8-bit RGBA colours? [2 marks]
- 1.4. Work out the angle between the two vectors, $\mathbf{V}_1 = 3\mathbf{i} - 2\mathbf{j}$ and $\mathbf{V}_2 = 2\mathbf{i} + 3\mathbf{j}$. [2 marks]
- 1.5. Calculate the unit vector of $\mathbf{V} = 3\mathbf{i} + 6\mathbf{j} - 2\mathbf{k}$. [2 marks]
- 1.6. What is an identity matrix and what is it used for in computer graphics? [2 marks]
- 1.7. Given two lines AB specified by A(-6,10) and B(12,6), and CD specified by C(6,8) and D(42,0), determine if they are parallel to each other. [2 marks]
- 1.8. Given a point in a 3D space represented in the homogeneous co-ordinates P(8, 6, 4, 2), what is the normal y co-ordinate value? [2 marks]
- 1.9. How could a 2D rectangle be scaled by a factor of 5 while its centre remains unchanged? [2 marks]
- 1.10. There are different matrix modes in OpenGL. Which one of **GL_MODELVIEW** and **GL_PROJECTION** should be used in conjunction with a **glRotate ()** function call and why? [2 marks]

Question 2. Transformations and viewing

[Total 20 marks]

- 2.1. For the 2D object shown in the figures below, work out the 2D homogeneous transformation matrix \mathbf{M} which transforms the 2D object in the left into the 2D object in the right (where $\alpha=45^\circ$). You can write the transformation matrix as a product of several simpler matrices (i.e., you do not have to multiply the matrices). A diagram can be used to aid your answer.

[8 marks]



- 2.2. Given the following fragment of code in OpenGL:

[8 marks]

```
void myDisply(void) {
    glViewport(0,0,300,200);

    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(-1,1,-1,1);

    glBegin(GL_QUADS);
        glColor3f(1,1,0);
        glVertex2f(-0.5,-0.5);
        glVertex2f(+0.5,-0.5);
        glVertex2f(+0.5,+0.5);
        glVertex2f(-0.5,+0.5);
    glEnd();
}
```

- a) Draw a diagram to illustrate the content generated on the screen.
 - b) Calculate the area of the displayed quad in pixels.
- 2.3. Explain the frustum volume and its implementation with OpenGL `glFrustum()`. A diagram can be used to aid your answer.

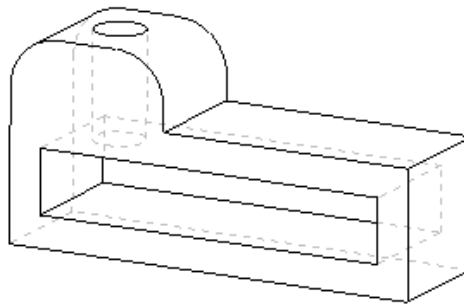
[4 marks]

Question 3. Geometric creation and modelling

[Total 20 marks]

- 3.1. A straight line is defined by $P_1(3,12)$ and $P_2(7,2)$. Determine the pixel positions with the DDA (Digital Differential Analyser) algorithm. A diagram can be plotted to demonstrate the result. [8 marks]

- 3.2. Identify if the following object is a manifold object using Euler's law. You can interpret the object by decomposing it into smaller units, based on which calculations are made. [8 marks]



- 3.3. Briefly discuss the concept of hierarchical modelling with an example. A diagram can be used to aid your answer. [4 marks]

Question 4. Lighting, materials and texture mapping [Total 20 marks]

4.1. The Phong lighting model can be written (without the distance terms) as

$$I = k_d I_d \mathbf{l} \cdot \mathbf{n} + k_s I_s (\mathbf{v} \cdot \mathbf{r})^\alpha + k_a I_a$$

Explain, with a diagram where necessary, each term of the model.

[8 marks]

4.2. The following OpenGL code defines a light source:

[4 marks]

```
GLfloat light_position[] = {1.0, 1.0, 1.0, 0.0};  
glLightfv(GL_LIGHT0, GL_POSITION, light_position);
```

- a) What type of light source is specified?
- b) Should distance attenuation be applied to this light and why?

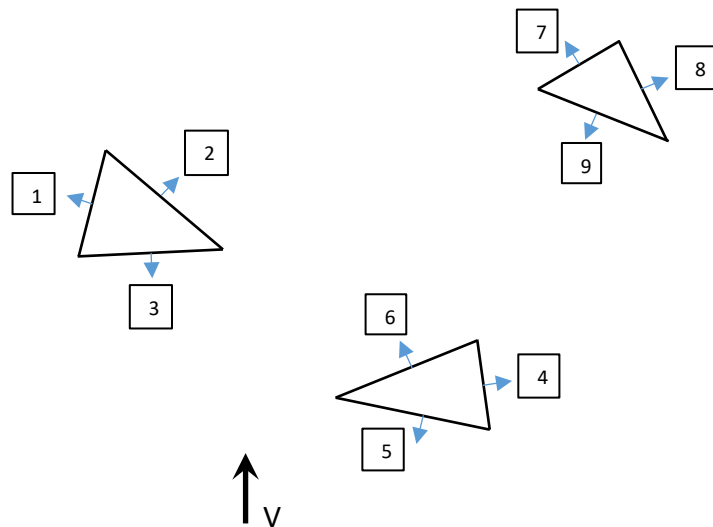
4.3. Mipmapping can be applied in texture mapping and it is implemented in graphic systems such as OpenGL. [8 marks]

- a) Briefly explain the need and concept for mipmapping.
- b) Given a texture map of 32*64 pixels at the highest level, work out the total number of levels for the maps and the size of each map.

Question 5. Clipping and hidden surface removal

[Total 20 marks]

- 5.1. Briefly discuss object space and image space algorithms for hidden surface removal. [6 marks]
- 5.2. Describe Brute force clipping of 2D lines (similar triangles) and its computational efficiency. A diagram can be used to aid your answer. [6 marks]
- 5.3. In the 2D figure below, each edge is a planar face in the triangle with its outward normal shown. You can assume that, if extended, no edge intersects another triangle. [8 marks]
- Build a BSP (Binary Spatial Partition) tree which uses the lines containing the edges to partition the 2-D space, and insert the edges into the tree.
 - Which edge would be drawn first if the viewer is at the location marked V?
 - Which edge would be drawn last if the viewer is at the location marked V?
 - Which edge(s) would be removed with backface culling?



THIS IS THE END OF THE EXAM.