U08181 Computer Graphics

Examination Rubric

Examination length: **2 hours**.

Answer any THREE questions.

All questions carry equal marks.

Examination Questions

1. a) Draw the output you would expect from the following SVG document and indicate the colour of each part.

```
<svg viewBox="0 0 200 200">
<style type="text/css">
        path {stroke:black}
        .s1 {fill:yellow}
        .s2 {fill:red}
        .s3 {fill:blue}
</style>

<defs>
   <path id="shape1" d="M0,0 L -20,-20 C -10 -50 10 -50 20 -20 z"/>
</defs>

<g transform="translate(100,100)">
   <g transform="translate(0,-5)">
   <use xlink:href="#shape1" class="s1"/>
   </g>
   <g transform="rotate(90)">
      <use xlink:href="#shape1" class="s2"/>
      </g>
   <g transform="rotate(180)">
      <use xlink:href="#shape1" class="s3"/>
   </g>
   <g transform="rotate(270)">
      <use xlink:href="#shape1" class="s2"/>
   </g>
</g>
</svg>
```

10 marks

b) Explain the mathematical representation of quadratic Bézier curves. It is not necessary to include mathematical formulae, but your answer should explain what is meant by a basis function and a sketch of the basis functions for quadratic Bézier curves.

6 marks

c) A line can also be thought of as a Bézier curve. For a line defined in the parametric form:

$$\mathbf{P}(t) = \mathbf{P}_1(1-t) + \mathbf{P}_2 t$$

What are the basis functions in this case? Sketch these functions for the parameter $\boldsymbol{t}$ in the range 0 to 1.

4 marks

d) "One important property of Bézier curves is affine invariance". Explain what this means.

3 marks

2. a) Describe how shapes can be represented in X3D using the IndexedFaceSet node. Include in your answer a description of the node's most important fields.

5 marks

b) Draw the shape represented by the following Shape node and indicate the colour of each face of the shape.

```
<Shape>
   <IndexedFaceSet coordIndex='0 5 1 -1, 0 3 4 5 -1, 3 2 4 -1,
                                        4 2 1 5 -1' solid="false">
    <Coordinate point="0 0 0, 0 0 1, 1 0 1, 1 0 0,
                              0.667 .4 .5, 0.333 0.4 0.5" />
   </IndexedFaceSet>
   <Appearance>
      <Material emissiveColor="0 1 0"/>
   </Appearance>
</Shape>
```

6 marks

c) Describe, how the shape described in part b) could be placed on top of a unit box (i.e. a box with side length 1, using Transform nodes. Give the values of the fields used. Indicate the position of the origin (the point (0, 0, 0)) in the resulting shape.

4 marks

d) Describe the effect of the following transformation on the composite shape defined in part c). Sketch the appearance of the resulting shape. Indicate clearly in your sketch the locations of the **x**, **y** and **z** coordinate axes. (*Hint*: 0.7854 radians = 45 degrees.)

```
<Transform rotation="0 1 0 0.7854">
            SHAPE
</Transform>
```

3 marks

e) "The CIE colour model provides a better basis for device independent colour specification than the RGB model." Explain why this is the case.

5 marks

3 a) Using a coordinate system in which **x** increases to the **right** and **y** increases **upwards**, sketch the shape formed by joining the points **A** at (0, 0), **B** at (1, 0) and **C** at (1, 1), clearly indicating the coordinates of each of the points.

1 mark

b) Calculate and write down the points formed by applying the matrix:

$$\begin{bmatrix} 2 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

to each of the points **A**, **B** and **C** that formed the shape you drew in part **a**. To do this, represent each point as a column vector with a 1 in the third row. Show your working.

3 marks

c) Sketch the resulting shape, clearly indicating the coordinates of points **A**, **B** and **C**.

1 mark

d) Calculate and write down the points formed by applying the matrix:

$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{bmatrix}$$

to each of the **original** points **A**, **B** and **C**. Show your working.

3 marks

e) Sketch the resulting shape, clearly indicating the coordinates of points **A**, **B** and **C**.

1 mark

f) Calculate and write down the points formed by applying the composed matrix:

$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 2 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

to each of the **original** points **A**, **B** and **C**. Show your working.

3 marks

g) Sketch the resulting shape, clearly indicating the coordinates of points **A**, **B** and **C**.

1 mark

h) The matrices you have used above are **homogeneous** matrices. Explain what a **homogeneous** matrix is.

2 marks

i) Explain why homogeneous matrices are useful in computer graphics.

3 marks

j) Given that the homogeneous matrix for rotation clockwise by **θ** ('theta') degrees around the origin, (0, 0) is:

$$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

show how you would **compose** a homogeneous matrix to rotate a shape about the point (x, y).

3 marks

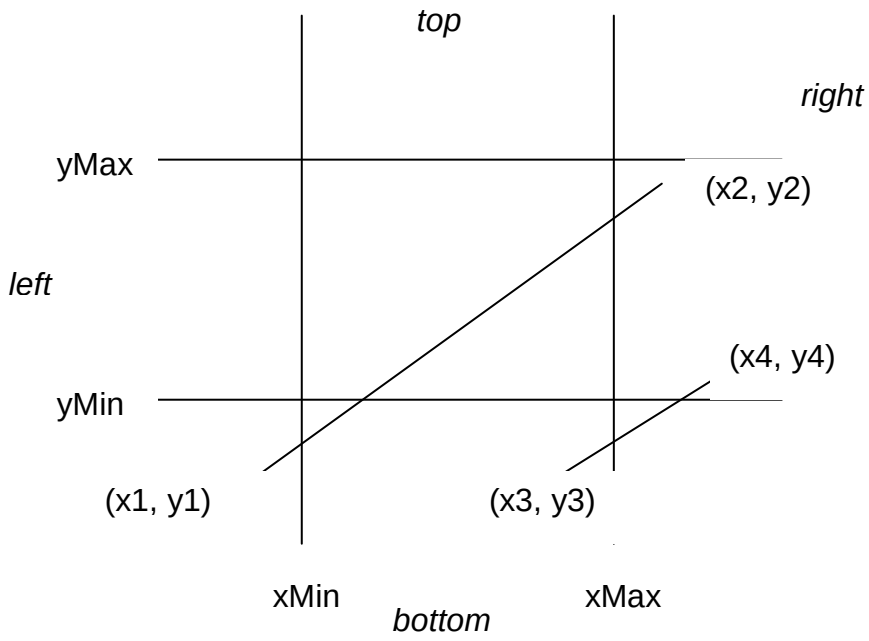
k) Write SVG statements to rotate an object defined within an SVG <g> element by theta degrees about a point (x, y).

2 marks

4 a) Explain the term **clipping** and give examples of where it is used in computer graphics.

3 marks

b) Assuming that **Region** has the values **left**, **right**, **top**, **bottom** and that a function **RegionSet(x, y)** returns the **set** of regions in which a point (x, y) falls with respect to a clipping rectangle (xMin, yMin) to (xMax, yMax, write down the values of RegionSet(x1, y1), RegionSet(x2, y2), RegionSet(x3, y3) and RegionSet(x4, y4) for the points as given on this diagram.



4 marks

c) Explain what it means if a point has an **empty** RegionSet.

2 marks

d) Explain what it means if a line from (xstart, ystart) to (xend, yend) has the property that the **intersection** of

RegionSet(xstart, ystart) and RegionSet(xend, yend)

is not the **empty** set.

2 marks

e) Sketch an example line that has such a property.

2 marks

f) Explain what it means if a line from (xstart, ystart) to (xend, yend) has the property that the **union** of

RegionSet(xstart, ystart) and RegionSet(xend, yend)

is the **empty** set.

2 marks

g) Sketch an example line that has such a property.

2 marks

h) Explain with the aid of sketches how the Cohen-Sutherland algorithm clips the line (x1, y1) to (x2, y2) in the diagram above to the rectangle (xMin, yMin) to (xMax, yMax).

3 marks

i) Explain how the Cohen-Sutherland algorithm clips line (x3, y3) to (x4, y4) in the diagram above to the rectangle (xMin, yMin) to (xMax, yMax).

3 marks

End of Examination Paper