U08181 Computer Graphics

Examination Rubric

Examination length: **2 hours**.

Answer any **three** questions.

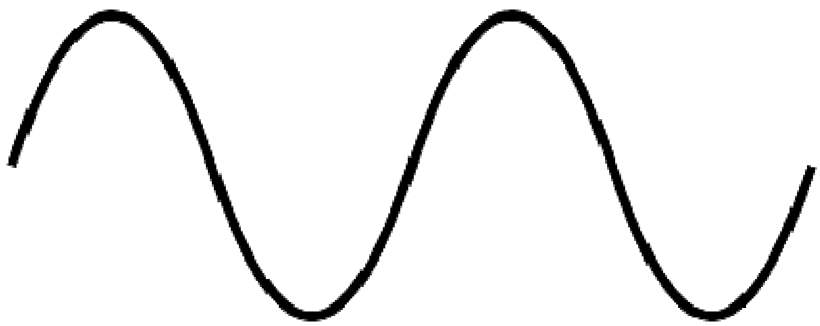
All questions carry equal marks.

Examination Questions

1. a) Describe with the aid of diagrams, how quadratic and cubic Bézier splines may be constructed using the SVG path descriptors **Q**, **T**, **C** and **S**. Your answer should explain the purpose of each of the four descriptors and how basis functions and control points determine the shape of splines. It is not necessary to give the equations that define these splines.

8 marks

b) The following curve can be represented in SVG using **quadratic** Bézier splines, using the **M**, **Q** and **T** path descriptors.



i) How many quadratic splines are required?

1 mark

ii) Clearly indicate on a diagram the approximate positions of the points associated with each spline.

3 marks

c) The following curve can be represented in SVG using **cubic** Bézier splines, using the **M**, **C** and **S** path descriptors. [Hint: think carefully about the symmetry of the curve and hence the symmetry of the control points.]

i) How many cubic splines are required?

1 mark

ii) Clearly indicate on a diagram the approximate positions of the points associated with each spline.

4 marks

d) Explain, with the aid of a diagram, the relationship between the RGB colour model and the CMY colour model.

2 marks

e) Convert the colour (0.75, 0.6, 0.4) expressed in the CMY colour model into the corresponding colour in the RGB colour model.

1 mark

2. a) Describe the main features supporting animation and interaction in X3D.

   Your answer should include descriptions of the following:

   Routes
   Sensor nodes
   TimeSensor
   Interpolation nodes.

8 marks

b) Sketch the shape represented by the following X3D code. Your sketch should indicate the orientation of the coordinate axes and the colour and dimensions of each object.

6 marks

```
<Scene>
 <Material  DEF="MAT1"  diffuseColor="1.0 0.0 0.0"/>
 <Material  DEF="MAT2"  diffuseColor="0.0 1.0 0.0"/>
 <Appearance  DEF="APP1" >
    <Material  USE="MAT1"/>
 </Appearance>
 <Appearance  DEF="APP2" >
    <Material  USE="MAT2"/>
 </Appearance>
 <Transform  translation="0.0 2.0 0.0">
    <Group >
       <Transform  translation="-3.5 0.0 0.0">
          <Shape  DEF="BOX1" >
             <Appearance  USE="APP2"/>
             <Cylinder  DEF="GEOM1"  radius="0.5" height="4.0"/>
          </Shape>
       </Transform>
       <Transform  translation="3.5 0.0 0.0">
          <Shape  USE="BOX1"/>
       </Transform>
       <Transform translation="0.0 2.5 0.0"
                  scale="1.0 2.0 1.0"
                  rotation="0.0 0.0 1.0 1.571">
          <Shape >
             <Appearance  USE="APP1"/>
             <Box  size="1.0 4.0 2.0"/>
          </Shape>
       </Transform>
    </Group>
 </Transform>
 </Scene>
```

c) Explain the effect of adding the following nodes to the code in part b).

3 marks

```
<ColorInterpolator DEF='COLOUR' key='0 0.5 1'
   keyValue='0 1 0 0.8 0.8 0.8 0 1 0'/>
<TimeSensor DEF='TIMER' cycleInterval='3' loop='true'/>
<ROUTE fromField='fraction_changed' fromNode='TIMER'
   toField='set_fraction' toNode='COLOUR'/>
<ROUTE fromField='value_changed' fromNode='COLOUR'
   toField='diffuseColor' toNode='MAT2'/>
```

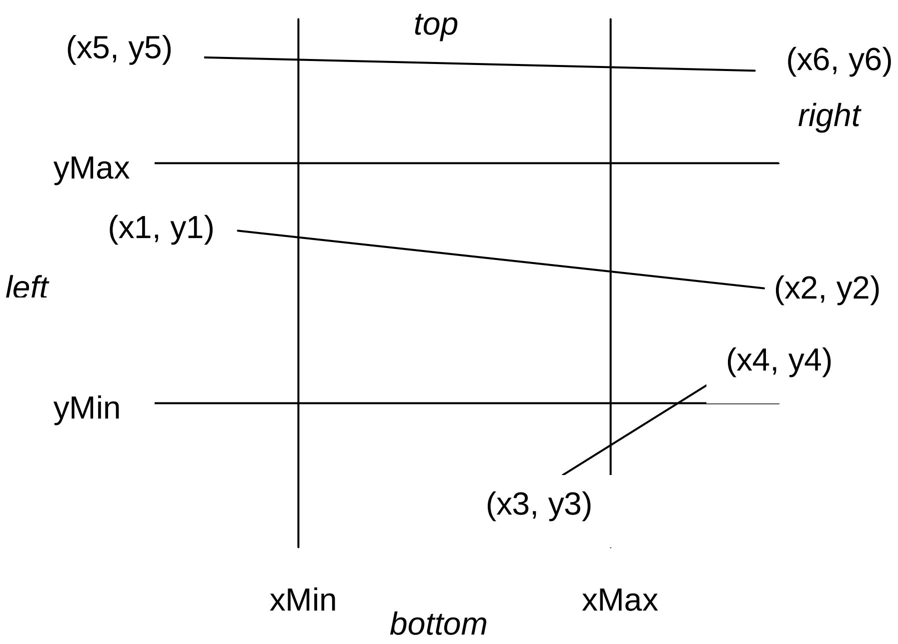
d) Explain how the X3D code could be modified to make the object rotate around the y-axis, completing one revolution every 3 seconds. [Hint: use an X3D OrientationInterpolator node to generate rotation values.]

3 marks

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

2 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)**, **RegionSet(x4, y4)**, **RegionSet(x5, y5)**, **RegionSet(x6, y6)** for the points as given on this diagram.



4 marks

c) Explain what it means if 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.

1 mark

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.

1 mark

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

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

1 mark

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

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

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 position. Show your working.

2 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:

$$\begin{bmatrix} 1 & 0 & 4 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix}$$

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

2 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:

$$\begin{bmatrix} 1 & 0 & 4 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 3 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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

2 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 scaling 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

End of Examination Paper