DELFT UNIVERSITY OF TECHNOLOGY
Faculty of Electrical Engineering, Mathematics and Computer Science
Department of Mediamatics

Computer Graphics (in2770)
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N.B.: This examination contains 30 questions
Total number of pages: 13

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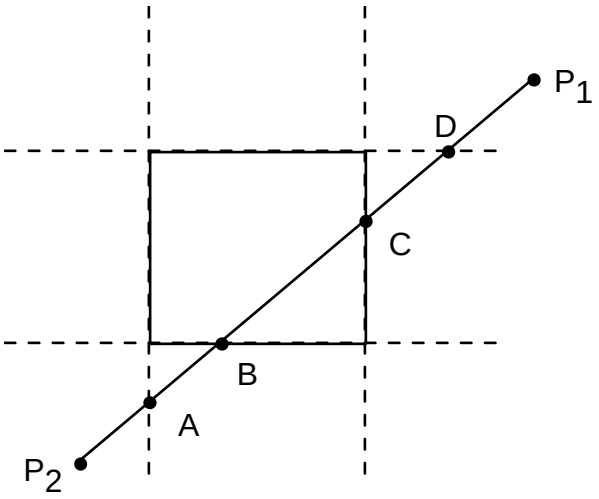
Question 2

How is the line P_1P_2 from the figure below clipped by the Cohen and Sutherland line clipping algorithm, with clipping order left, right, bottom, top?



a. P_1P_2 -> P_1A -> CA -> CB
b. P_1P_2 -> DP_2 -> CP_2 -> CA -> CB
c. P_1P_2 -> CP_2 -> CA -> CB
d. P_1P_2 -> P_1A -> P_1B -> CB

Question 3

When generating a computer image, there are some important differences between rendering on a *random scan* device and on a *raster scan* device.
For both types of device, we want an answer to the following questions:

- Is scan conversion needed on this type of device as one of the steps in the rendering pipeline?
- Can shaded images be easily made on this type of device?

How must the table below be filled in?

	random scan device	**raster scan device**
scan conversion needed?	(i)	(ii)
suitable for "shaded" images?	(iii)	(iv)

	(i)	(ii)	(iii)	(iv)
a.	yes	no	yes	no
b.	yes	no	no	yes
c.	no	yes	yes	no
d.	no	yes	no	yes

Question 4

What is an important difference between a *field* and an *exposed field* in VRML?

a. An exposed field has an implicit event-in and an implicit event-out. A field does not have any implicit events.
b. An exposed field influences an aspect of a node that can be visualized in a virtual world. A field does not influence any aspects of a node that have a direct influence on the virtual world.
c. An exposed field reacts on user interaction. A field does not.
d. An exposed field can be assigned a list of values. A field can only get values of a primitive type.

Question 5

With which factor is the size of the frame buffer reduced, if a color lookup table is used with 256 entries for a color choice from a palet with 2^{24} colors?

a. 3
b. 2^3
c. 16
d. 2^{16}

Question 6

The Cohen and Sutherland algorithm for clipping a line against a rectangular window in 2D can easily be adapted to a 3D algorithm for clipping a line against a 3D block shaped viewing volume. In 3D, like in 2D, codes can be used for the end points of the line to be clipped, depending on their position relative to the viewing volume.
Consider the following questions:

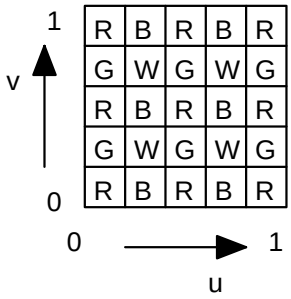
(I) How many bits are needed for the code of a line end point in 3D?
(II) How many different areas (with differing codes) must be distinguished in 3D?

The correct answers to these questions are:

	(I) number of bits	(II) number of areas
a.	4	27
b.	4	64
c.	6	27
d.	6	64

Question 7

Given is the texture that is shown below, with colors R (red), G (green), B (blue) and W (white).



The texture is mapped on a polygon ABCD using *linear interpolation along the edges of the polygon followed by linear interpolation along the scan lines*. The table below shows the correspondence between vertices of the polygon in screen coordinates and the texture coordinates of the points which are mapped on these four vertices.

Vertex	Screen coordinates		Texture coordinates	
	x	y	u	v
A	50	150	0	0
B	520	0	1	0
C	280	400	1	1
D	170	350	0	1

Which color gets pixel P (240, 300) when this mapping is applied?

a. R (red)
b. G (green)
c. B (blue)
d. W (white)

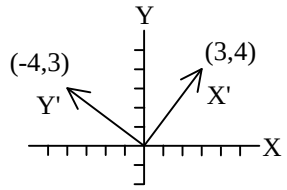
Question 8

A rotation about the line $l: \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$ with the angle θ = +90° has the following homogeneous coordinate matrix:

a. $\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$ b. $\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & -1 & 0 & -1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$ c. $\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$ d. $\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

Question 9

An object in a 2D world coordinate system must be rendered under an angle that is defined by a view up vector $\mathbf{v} = \begin{pmatrix} -4 \\ 3 \end{pmatrix}$. Therefore, a transformation is applied that transforms objects from a world coordinate system XY to a coordinate system X'Y', where the Y' axis direction is defined by **v** and the origin is the same as the origin of the XY system.



What is the correct matrix for the transformation of objects from the XY to the X'Y' system?

a. $\begin{pmatrix} -0.6 & 0.8 & 0.0 \\ -0.8 & -0.6 & 0.0 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$

c. $\begin{pmatrix} 0.6 & 0.8 & 0.0 \\ -0.8 & 0.6 & 0.0 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$

b. $\begin{pmatrix} -0.8 & 0.6 & 0.0 \\ -0.6 & -0.8 & 0.0 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$

d. $\begin{pmatrix} 0.8 & 0.6 & 0.0 \\ -0.6 & 0.8 & 0.0 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$

Question 10

A = (0, 0), B = (0, 1), C = (1, 1) and D = (1, 0) are four points in texture space. The quadrilateral ABCD in texture space is mapped on an arbitrary convex quadrilateral in screen space. Which of the three types of mappings, summed below, map lines AD, BC and every other horizontal line in texture space always on a straight line in screen space?
(i) perspective mapping
(ii) bi-linear mapping
(iii) linear interpolation on edges, followed by linear interpolation on scan lines

a. none of these three types of mappings
b. only (i)
c. only (i) and (ii)
d. (i), (ii) and (iii)

Question 11

What is a reason to make use of pre-filtering with a mip-map for antialiasing a texture on a polygon?

a. A mip-map enlarges the accuracy of the filtering.
b. A mip-map makes the processor time needed to determine the filtered value, independent of the amount of compression of the texture on the projection of the polygon.
c. A mip-map enables super sampling.
d. A mip-map enables an arbitrary homogeneous scaling of the texture, while mapping on a polygon.

Question 12

In a computer animation of an object, the position of the object between two key frames is determined by linear interpolation. The orientation is determined by linear interpolation of three rotation angles (about the x-axis, the y-axis and the z-axis).
Given is that the modeling transformation *M*i transforms the object to its position and orientation at the time belonging to key frame *K*i. The following modeling transformations belong to the first and second key frames:

$$M1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad M2 = \begin{pmatrix} 0 & -1 & 0 & 4 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Which transformation matrix defines the objects position and orientation at a frame in the middle between the key frames *K*1 and *K*2?

a. $\begin{pmatrix} \frac{1}{2} & -\frac{1}{2} & 0 & 2 \\ \frac{1}{2} & \frac{1}{2} & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

b. $\begin{pmatrix} \frac{1}{2}\sqrt{2} & -\frac{1}{2}\sqrt{2} & 0 & 2 \\ \frac{1}{2}\sqrt{2} & \frac{1}{2}\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

c. $\begin{pmatrix} \frac{1}{2} & -\frac{1}{2} & 0 & 4 \\ \frac{1}{2} & \frac{1}{2} & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

d. $\begin{pmatrix} \frac{1}{2}\sqrt{2} & -\frac{1}{2}\sqrt{2} & 0 & 4 \\ \frac{1}{2}\sqrt{2} & \frac{1}{2}\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

Question 13

What is the OpenGL function call `glShadeModel(…)` used for?

a. for making a choice between flat shading and Gouraud shading
b. for making a choice between different types of light sources
c. for choosing the light reflection model (for instance the model of Phong)
d. for choosing the components of the light reflection model (for instance specular reflection or not)

Question 14

When using back-face removal for 3D models consisting of polyhedral solid objects, polygons are removed. Which statement is correct?

a. All polygons which are completely invisible, are removed.
b. All polygons which are completely or partly invisible, are removed.
c. A number of polygons which are completely invisible, are removed.
d. A number of polygons which are completely or partly invisible, are removed.

Question 15

The following VRML 2.0 node transforms the object or the group of objects, which are defined in the list `[...]`.

```
Transform {
  translation 1.0 1.0 0.0
  children Transform {
    rotation 0.0 0.0 1.0 0.785
    children Transform {
      translation -1.0 -1.0 0.0
      children [...]
    }
  }
}
```

Which node applies the same transformation to the list of objects `[...]` as the node above?

a.
```
Transform {
  rotation 0.0 0.0 1.0 0.785
  center 1.0 1.0 0.0
  children [...]
}
```

b.
```
Transform {
  rotation 0.0 0.0 1.0 0.785
  center -1.0 -1.0 0.0
  children [...]
}
```

c.
```
Transform {
  rotation 0.0 0.0 1.0 -0.785
  center 1.0 1.0 0.0
  children [...]
}
```

d.
```
Transform {
  rotation 0.0 0.0 1.0 -0.785
  center -1.0 -1.0 0.0
  children [...]
}
```

Question 16

Somebody implements the DDA line scan conversion algorithm in the following way:

```
#define ROUND(a) ((int) (a+0.5))

void lineDDA (int xa, int ya, int xb, int yb)
{
  int dx = xb - xa, dy = yb - ya, steps, k;
  float xIncrement, yIncrement, x = xa, y = ya;

  if (dx > dy)
    steps = dx;
  else
    steps = dy;
  xIncrement = dx / (float) steps;
  yIncrement = dy / (float) steps;

  glBegin (GL_POINTS);
    glVertex2i (ROUND(x), ROUND(y));
  glEnd ();
  for (k=0; k<steps; k++) {
    x += xIncrement;
    y += yIncrement;
    glBegin (GL_POINTS);
      glVertex2i (ROUND(x), ROUND(y));
    glEnd ();
  }
}
```

Given are the following calls of `lineDDA`:

(i) `lineDDA(10, 10, 50, 200)`
(ii) `lineDDA(10, 10, 200, 50)`
(iii) `lineDDA(200, 10, 10, 50)`

Which call (or calls) of `lineDDA` draw the line segment on the correct position and without any holes?

a. only call (i)
b. only call (ii)
c. only calls (i) and (ii)
d. only calls (ii) and (iii)

Question 17

What is a ROUTE in VRML?

a. the path traveled by an object in an animation
b. a chain of events between nodes
c. a list of 3D points, which are used in a PositionInterpolator node
d. a hierarchy of nodes in the VRML file

Question 18

Given are two vectors **v** and **w** that are not parallel (i.e. there is **no** real number λ for which $\mathbf{v} = \lambda\,\mathbf{w}$ holds).
The cross product of **v** and **w** is written as $\mathbf{v} \times \mathbf{w}$.

Consider the statements below:

(I) The cross product $\mathbf{v} \times \mathbf{w}$ is perpendicular to the vectors **v** and **w**.
(II) The vectors **v**, **w** and $\mathbf{v} \times \mathbf{w}$ constitute a right handed coordinate system.
(III) The length of $\mathbf{v} \times \mathbf{w}$ is equal to the area of the parallelogram, formed by **v** and **w**.

How many of these statements are correct?

a. 0
b. 1
c. 2
d. 3

Question 19

The matrix

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

is the transformation matrix of a 3D elementary transformation. What kind of transformation is this?

a. translation
b. rotation
c. scaling
d. shearing

Question 20

For which type of projection the following holds: "there is one projection direction and this direction is <u>not</u> perpendicular to the projection plane"?

a. orthographic projection
b. perspective projection
c. isometric projection
d. cabinet projection

Question 21

In the window to viewport transformation, a window (in world coordinates) is mapped on a viewport (in screen coordinates).

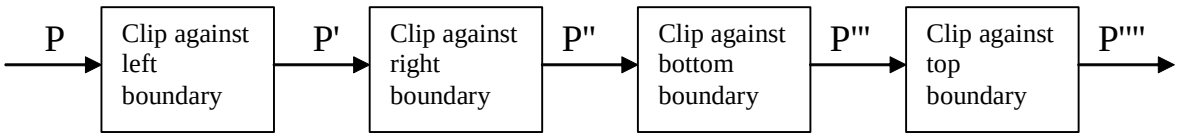
Consider the following statements:
(I) The effect of zooming is derived by scaling the ..... .
(II) The effect of panning is derived by translating the ..... .

By which words (*window* or *viewport*) must ..... be substituted in order to get correct statements?

	in statement (I)	in statement (II)
a.	window	window
b.	window	viewport
c.	viewport	window
d.	viewport	viewport

Question 22

The Sutherland Hodgman polygon clipping algorithm clips an (input) polygon in the following way: Clip the input polygon against one of the extended window boundaries. The resulting output polygon is the input polygon for the clipping step against the next extended window boundary. Clip against all four window boundaries in this way. This process is shown in the figure below.



Consider the following statements about the Sutherland Hodgman algorithm:

(I) When clipping against one of the extended window boundaries, it is *impossible* that the output polygon has *less* vertices than the input polygon.
(II) When clipping against one of the extended window boundaries, it is *impossible* that the output polygon has *more* vertices than the input polygon.

Are the statements (I) and (II) correct or not?

	(I)	(II)
a.	correct	correct
b.	correct	incorrect
c.	incorrect	correct
d.	incorrect	incorrect

Question 23

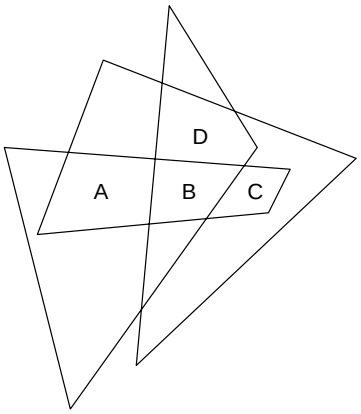
One of the algorithms for hidden surface removal is the z-buffer algorithm. What is stored in the z-buffer?

a. For every polygon the polygon distance to the observer is stored.
b. For every polygon is stored, whether the projection of the polygon intersects the current scan line.
c. For every pixel is stored, whether the projection of the current polygon overlaps the pixel.
d. For every pixel the smallest z-direction distance to one of the polygons, that already have been scan converted and overlap the pixel, is stored.

Question 24

There are two regular rules (with different results) to determine the interior of a polygon:
- the "odd-even" rule
- the "nonzero winding number" rule

Which area in the figure below is according to both rules inside the polygon or according to both rules outside the polygon?



a. A
b. B
c. C
d. D

Question 25

With a call of which OpenGL function the viewing coordinate system is defined?

a. `glOrtho`
b. `glFrustrum`
c. `gluPerspective`
d. `gluLookAt`

Question 26

Given is the type declaration

```
typedef GLint point3D[3];
```

and the program fragment

```
point3D points[6] = {{100, 100, 50}, {20, 50, 30},
{40, 30, 20}, {80, 20, 10}, {110, 40, 20}, {140, 70, 30}};

glBegin (GL_TRIANGLE_FAN);
  for (i=0; i<6; i++)
    glVertex3iv (points[i]);
glEnd ();
```

How many polygons are created by this program fragment?

a. 2
b. 3
c. 4
d. 5

Question 27

Let N_1 ... N_k be the (unit) normal vectors of the k polygons that have a vertex v in common.

Consider the following calculation: $N_v = \frac{\sum_{k=1}^{n} N_k}{\left|\sum_{k=1}^{n} N_k\right|}$

In which shading method(s) this calculation must be applied?

a. only in flat shading
b. only in Gouraud shading
c. only in Phong shading
d. in Gouraud shading and in Phong shading

Question 28

Given the 3D points P = (2, 5, 1), Q = (2, 5, -3) and R = (5, 2, 4). What is the correct plane equation of the plane that contains polygon PQR, where coefficient d has not yet been calculated?

a. -x+y+d = 0
b. -x+y-z+d = 0
c. -x-y+z+d = 0
d. -x-y+d = 0

Question 29

What is the (most important) reason to use homogeneous coordinates to represent transformations (translation, rotation, scaling and shearing)?

a. All transformations can be expressed with a matrix, when using homogeneous coordinates.
b. The transformation equations are less complex with homogeneous coordinates.
c. Only for homogeneous coordinates the commutative rule holds when multiplying matrices that represent elementary transformations.
d. The shearing transformation only exists for homogeneous coordinates.

Question 30

Given the light reflection model $I = k_a I_a + \frac{1}{d^2} I_l \left[k_d (N \bullet L) + k_s (N \bullet H)^{n_s} \right]$

Consider the following statements about this model:

(I) When the light source is at infinity, then the factor $\frac{1}{d^2}$ must be removed from the model.

(II) When the light source is at a finite distance, then the vector L must be recalculated for every new point on a visible surface where the light reflection model is applied..

Are the statements (I) and (II) correct or not?

	(I)	(II)
a.	correct	correct
b.	correct	incorrect
c.	incorrect	correct
d.	incorrect	incorrect

end of examination