Please read these instructions carefully!

- Answer the test questions in the separate answer sheet.
- You may use the back of all the paper sheets as drafting area (*rascunho*).
- How to:

	A	B	C	D	E
Select the answer (A):	●	○	○	○	○
Replace the answer (A) by (C):	✗	○	●	○	○
Cancel (C) and reactivate (A):	◉	○	✗	○	○

- This test has **??** QUESTIONS, each question has a score of 200/**??** points.
- **POINTS LOST** for each wrong answer (in percentage of the question's points):
  $\sum wrong$ $1 = 0\%$ $2 = 11.11\%$ $3 = 22.22\%$ $\geq 4 = 33.33\%$.

Name: ____________________ Number: __________

Consider the pipeline of a modern graphics card programmed through the WebGL API. The GLSL program that is being executed is presented in the following listing. Apart from the vertex positions and a set of corresponding texture coordinates, the GLSL program also receives the Model, View and Projection matrices.

```
// vertex shader
attribute vec4 vPos;
attribute vec2 vTex;
uniform mat4 mModel;
uniform mat4 mView;
uniform mat4 mProj;
varying vec2 fTex;

main()
{
  gl_Position = ... ;
  fTex = vTex;
}

// fragment shader
varying vec2 fTex;
uniform sampler2D tex;
main()
{
  gl_FragColor = texture2D(tex, fTex);
}
```

1. What is the typical value assigned to `gl_Position` to get the vertex location in Clip Coordinates?
   A. `mProj * mView * mModel * vPos`
   B. `mModel * mView * mProj * vPos`
   C. `mView * mModel * mProj * vPos`
   D. `mProj * mModel * mView * vPos`
2. What is the expression to compute the vertex location in World Coordinates (WC)?
   A. `vPos`
   B. `mProj * vPos`
   C. `mView * vPos`
   D. `mModel * vPos`
3. What is the matrix that transforms vertex cooordinates from World Coordinates to Camera Coordinates?
   A. `mView`. B. `mModel * mView`. C. `mView * mModel`. D. `mProj`.
4. Let H be the convex hull defined by the values of `vTex` at the vertices of the primitive being drawn. The value of `fTex` that reaches the fragment shader . . .
   A. . . . is always inside H.
   B. . . . is sometimes inside H and sometimes outside it.
   C. . . . is always on the boundary of H.
   D. . . . is always outside H.
5. The GLSL program presented above is invoked by the javascript side of the application . . .
   A. . . . through a call of either `drawElements(...)` or `drawArrays(...)`
   B. . . . through a call of `useProgram(...)`
   C. . . . through a call of `drawArrays(...)`
   D. . . . through a call of `drawElements(...)`
6. Values for the attributes `vPos` and `vTex` need to be stored by the javascript side of the application in . . .
   A. any of the other answers is possible.
   B. . . . two WebGL buffers
   C. . . . a single WebGL buffer with the values for each attribute in contiguous memory positions.
   D. . . . a single WebGL buffer with the values for each attribute alternating in memory.
7. The GLSL program above applies a texture to the primitives. What can be said about the specific type of mapping?
   A. Cilindrical mapping. B. Orthogonal mapping. C. Nothing. D. Texture atlas.

8. Which values would you use for the parameters `TEXTURE_MAG_FILTER` and `TEXTURE_MIN_FILTER` so that, (i) when the polygon is bigger than the texture, the texel closer to the point with coordinates `fTex` is used, and (ii) when the polygon is smaller than the texture, the 2x2 texels closer to the point with coordinates `fTex` are used? **Note:** the answer must be given in the corresponding order of the parameters.

   A. `LINEAR, NEAREST` B. `NEAREST, NEAREST` C. `NEAREST, LINEAR` D. `LINEAR, NEAREST`

A WebGL application displays an endless star field simulation. In this simulation, we are perpetually moving in a straight line, at constant speed, and stars appear against a black background, following a path in a direct line that pushes them away from the center of the screen. Stars move on screen at different speeds, depending on their distance to the camera. The simulation is going to be performed in 3D, using Camera Coordinates. So, instead of moving the camera in space, stars are moved relative to the camera position. Each star will correspond to a vertex drawn using the `POINTS` primitive. Stars have different sizes and, to avoid a pop up effect when they appear, varying opacity will be used.

9. What are the attributes required ?
   - A. current position and time of creation
   - B. size, current values for position, speed and opacity
   - C. size, initial position and time of creation
   - D. size, current values for position and speed, and additional time of creation

10. What are the uniforms required?

    A. current time B. camera speed C. current time and camera speed D. current time, size and camera speed.

11. What type of projection would you use in this simulation?

    A. perspective B. orthogonal C. axonometric D. oblique

Consider the following composition of elementary geometric transformations that is used as the model transformation of a given 3D primitive.

$$M = T(2,0,0) \cdot S(3,1,3) \cdot R_y(45°) \cdot S(1,3,1/2) \cdot R_z(30°) \cdot S(2,2,4)$$

In ray tracing, a ray is composed of a origin o and a direction d. Rays are created using World Coordinates. As the ray is tested against each primitive, the low level ray-primitive intersection tests are performed in Object Coordinates (or Modelling Coordinates).

12. How can the ray origin be computed in Object Coordinates?

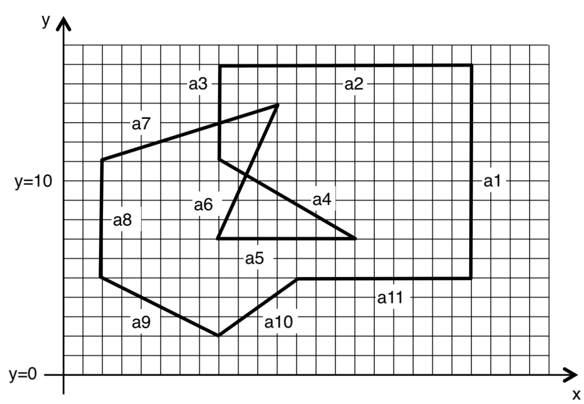
    A. $M \cdot \mathrm{p}$ B. $M^{-1} \cdot \mathrm{p}$ C. $(M^T)^{-1} \cdot \mathrm{p}$ D. $((M^{-1})^T)^{-1} \cdot \mathrm{p}$

13. How can the ray direction be computed in Object Coordinates?

    A. $((M^{-1})^T)^{-1} \cdot \mathrm{d}$ B. $(M^T)^{-1} \cdot \mathrm{d}$ C. $M \cdot \mathrm{d}$ D. $M^T \cdot \mathrm{d}$

14. What is the simplest expression for M?
    - A. $T(2,0,0) \cdot S(3,1,3) \cdot R_y(45°) \cdot R_z(30°) \cdot S(2,6,2)$
    - B. $T(2,0,0) \cdot S(3,1,3) \cdot R_y(45°) \cdot S(1,3,1/2) \cdot R_z(30°) \cdot S(2,2,4)$
    - C. $T(2,0,0) \cdot R_y(45°) \cdot S(3,1,3/2) \cdot R_z(30°) \cdot S(2,2,4)$
    - D. $T(2,0,0) \cdot R_y(45°) \cdot R_z(30°) \cdot S(6,6,6)$

Consider the polygon on the right, defined by its edges $a_1, \ldots, a_{11}$.



15. Choose a set of pixels that are painted by the midpoint algorithm when applied to edge a_7.
    - A. $(2,11),(3,11),(4,12),(6,12)$
    - B. $(2,11),(3,12),(4,13),(6,13)$
    - C. $(2,11),(3,12),(4,12),(6,13)$
    - D. $(2,11),(3,11),(4,11),(6,12)$

The same polygon will be painted using the Fillarea/Scanline algorithm.

16. How many edges will be stored in the Edges Table (TA)?

A. 11 B. 9 C. 10 D. 8

17. What is the sequence of active edges for scanline $y = 5$?

A. $a_8 \to a_9 \to a_{10} \to a_1$ B. $a_8 \to a_{11} \to a_1$ C. $a_8 \to a_1$ D. $a_9 \to a_{10}$

18. What is the sequence of active edges for scanline $y = 7$?

A. $a_6 \to a_4$ B. $a_8 \to a_6 \to a_4$ C. $a_8 \to a_6 \to a_4 \to a_1$ D. $a_8 \to a_1$

19. What is the sequence of active edges for scanline $y = 11$?

A. $a_7 \to a_3 \to a_6 \to a_1$ B. $a_8 \to a_6 \to a_4 \to a_1$ C. $a_8 \to a_4 \to a_6 \to a_1$ D. $a_7 \to a_3 \to a_4 \to a_1$

20. What is the information that the algorithm stores in the Edges Table (TA) for edge a_{10} ?

A. $\{8, 2, 3/4\}$

B. $\{12, 5, 4/3\}$

C. $\{8, 5, 3/4\}$

D. $\{8, 5, 4/3\}$

21. Choose the answer that contains two of the pixels that will be painted by the scanline algorithm.

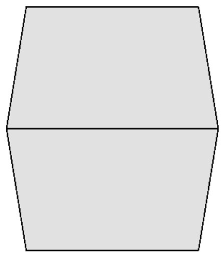
A. (12, 5) and (8,11)

B. (2,5) and (8,7)

C. (2,5) and (15,7)

D. (8,2) and (2,5)

A cube was projected using a planar geometric projection and the result is shown in the right figure.



22. What type of projection has been used?

A. oblique cabinet

B. oblique cavalier

C. perspective

D. axonometric

23. What can be said about the orientation of the cube edges relative to the projection plane?

A. one set of parallel edges is parallel to the projection plane

B. two sets of parallel edges are parallel to the projection plane

C. no edges are parallel to the projection plane

D. three sets of parallel edges are parallel to the projection plane

24. With which type of projection could we see two faces of the cube with its real dimensions?

A. axonometric trimetric projection

B. perspective projection

C. axonometric dimetric projection

D. oblique projection

25. Which techniques could have been used to remove the hidden surfaces from the image?

A. back-face culling

B. either the z-buffer or the back-face culling

C. Z-buffer

D. z-buffer and back-face culling simultaneously

A certain workstation has a display resolution of 1920×1080 pixels, with the origin located on the top left corner. At the top of the screen we want to reserve space for a bar with 280 pixels in height, where a navigation bar for a document is to be displayed. In the remainder lower part of the screen we want to display the contents of two full A4 pages, in portrait mode. The contents of the pages are to be displayed without deformation and without clipping its contents. The two pages will be next to each other without any space between them and centered horizontally. The A4 pages have their origin at the lower left corner and have a dimension of 210x297 units.

26. What would be the first transformation to be applied as part of the window to viewport transformation of the left page?

A. $T(0, -297)$ B. $T(-210, -297)$ C. $T(-210, 0)$ D. $T(0, 0)$

27. What would be the last transformation to be applied as part of the window to viewport transformation of the left page?

A. $T(0, 280)$ B. $T(0, 1080)$ C. $T(960, 280)$ D. $T(960, 1080)$

28. What would be the scaling transformation to be used in the window to viewport transformation of the left page?

A. $S(\frac{800}{297}, \frac{800}{297})$ B. $S(\frac{960}{210}, -\frac{960}{210})$ C. $S(\frac{960}{210}, -\frac{800}{297})$ D. $S(\frac{800}{297}, -\frac{800}{297})$

Let us consider now the right page…

29. What would be the first transformation to be applied as part of the window to viewport transformation of the right page?

A. $T(-210, -297)$ B. $T(0, -297)$ C. $T(0, 0)$ D. $T(-210, 0)$

30. What would be the last transformation to be applied as part of the window to viewport transformation of the left page?

A. $T(0, 1080)$ B. $T(0, 280)$ C. $T(960, 280)$ D. $T(960, 1080)$

Consider the variant of the Phong illumination model computed by the expression below, for direct illumination (surfaces directly visible to the eye):

$$\mathrm{I} = \mathrm{I}_a \mathrm{K}_d + \mathrm{I}_p[\mathrm{K}_d \cos(\alpha) + \mathrm{K}_s \cos(\phi)^n].$$

31. For a specular reflection factor of RGB(0.5,0.5,0.5), what will be the color of the specular highlights?

A. K_d B. $\mathrm{I}_p/2$ C. $\mathrm{I}_a * 2$ D. $\mathrm{K}_s/2$

32. The amount specular reflection is maximized when:

A. N and L are parallel. B. R and V are parallel. C. L and V are parallel. D. N and H are parallel.

33. The amount of reflected light given by the specular term is porportional to the n^{th} power of the cosine of the angle formed between:

A. R and L B. V and L C. N and L D. R and V

34. Assume that the specular term was set to 0 before lighting an object, which has unknown color, with two different light sources, both aligned in a way that maximize the diffuse reflection. The ambient light was set to RGB(1,1,1), and the light colors were RGB(0,1,1) and RGB(1,0,1), for which the observed colors of the object were RGB(0.3, 0, 0.4) and RGB(0.6, 0, 0.4), respectively. What is the color of the object?

A. (0.6, 0, 0.4).

B. (0.3, 0, 0.2).

C. (0.3, 0, 0.4).

D. (0.6, 0, 0.2).

Boa Sorte!