

# Graphics (INFOGR 2015-2016): Example Exam

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**Do not open the exam until instructed to do so!**

**Read the instructions on this page carefully!**

- You may write your answers in English or Dutch. Use a pen, not a pencil. Do not use red or green. Please write clearly!
- Fill in your name and student ID at the top of this page, and write it on every additional paper you want to turn in.
- Answer the questions in the designated areas on these exam sheets. If you need more space for a problem, state this in the designated area for the problem and continue on the paper provided by us. On the additional paper, state your name and student ID, make sure to clearly indicate the problem number and start a new page for each problem. For math questions 2 and 3, if possible, copy the main steps to the exam paper after solving the problem on scrap paper.
- You may not use books, notes, or any electronic equipment (including your smartwatch and cellphone, even if you just want to use them as a clock).
- You have max. 2 hours to work on the questions. If you finish early, you may hand in your work and leave, except for the first half hour of the exam. When you hand in your work, have your student ID ready for inspection.
- The exam has 2 parts printed on 4 pages (including this one). It is your responsibility to check if you have a complete printout. If you have the impression that anything is missing, let us know.
- This exam includes one bonus question, for 10 points, which means the maximum score is 110 points. Your score will be capped at 100 points, should this be relevant.

Good luck / veel succes!

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|                         | Points |
|-------------------------|--------|
| Part 1: Mathematics     |        |
| Part 2: Graphics Theory |        |

Total points: \_\_\_\_\_

1. Given: an eye position  $E = (1,1,1)$ , a view vector  $\vec{V} = (1,0,1)$ , an up vector  $\vec{up} = (0,1,0)$ , a FOV of 90 degrees and a screen resolution of 512x512 pixels. (for 5x5 points)

- a. For the purpose of ray tracing, calculate the four corners of a virtual screen plane at a distance 1 from  $E$ , perpendicular to  $\vec{V}$  and  $\vec{up}$ , taking into account the specified FOV.

Top-left corner: ..... Top-right corner: .....

Bottom-left: ..... Bottom-right: .....

- b. Determine the normalized direction of ray  $r$ , which originates from  $E$  and extends through pixel (0,256).

Ray direction: .....

- c. Determine the 3D coordinate of the intersection of  $r$  with the plane:  $-X - Z = 10$ .

Intersection point: .....

- d. Calculate the intersection of  $r$  with the sphere  $\|p - C\| = \sqrt{20}$ , where  $C = (-1,1,-1)$ .

Intersection point: .....

- e. Point  $P = (\sqrt{10} - 1, 1, \sqrt{10} - 1)$  is a point on the sphere  $\|p - C\| = \sqrt{20}$ . Calculate the normalized shading normal for  $P$  on the inside of the sphere.

Normal: .....

2. Culling schemes that mark some objects as visible when they are not (but not the other way round) are called: (for 5 points)

.....

3. Glass causes two types of scattering. Name both. First type: .....  
(for 5 points)

Second type: .....

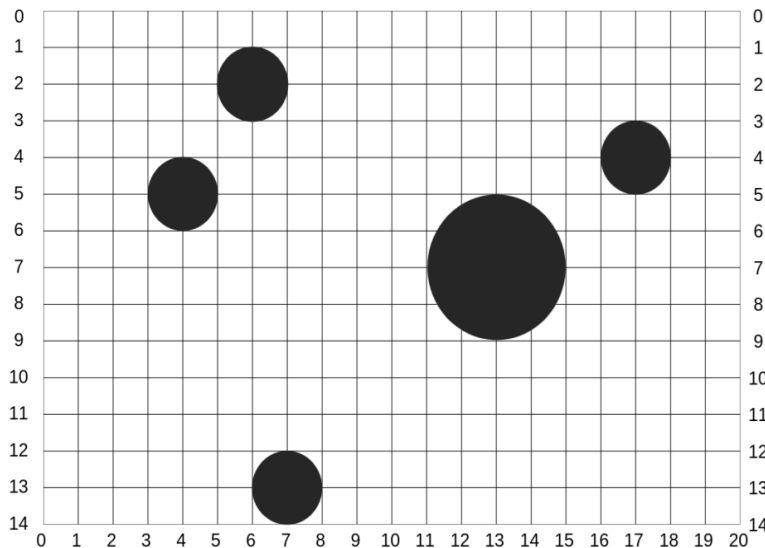
4. Observe the three images below, and fill in the missing parts. (for 10 points)

The left image shows blocky textures due to ..... . In the center image, this is not as noticeable thanks to the use of ..... . In the image on the right, distant road sections would have suffered from ..... , but clearly ..... was used to combat this. The horizontal bands would have been reduced if the renderer would also have supported .....



5. Given: a scene with 5 discs, as shown below. Determine the best split using the Surface Area Heuristic. Consider only vertical splits, assume integer coordinates only, and assume that objects on a split plane are assigned to the left side. Write down the best split plane position, the cost before splitting and the cost after splitting. (for 15 points)

Note: since this is a 2D scene, use circumference as you would normally use surface area.



Cost before splitting:

.....

Position of best split plane:

.....

Cost after splitting:

.....

.....

.....

6. The two vectors  $(-2,1)$  and  $(1,2)$  are...
- a) ...linearly dependent of each other
  - b) ...forming an orthonormal basis
  - c) ...perpendicular to each other
  - d) ...pointing in the opposite direction of each other
  - e) none of the above.
7. The scalar product (aka dot product) of two perpendicular vectors is
- a) ...0
  - b) ...1
  - c) ...2 PI
  - d) ...-2 PI
  - e) none of the above.
8. If  $s$  is a scalar value and  $\vec{v}, \vec{w}$  are two vectors in  $\mathbb{R}^3$ , then the result of  $s + (\vec{v} \times \vec{w}) \cdot (\vec{v} \times \vec{w})$  is...
- a) ...a vector in  $\mathbb{R}^3$
  - b) ...a scalar
  - c) ...undefined
  - d) ...a 3 by 3 matrix.
9. If the angle between two vectors (both having a non-zero magnitude) is greater than  $90^\circ$  and smaller than  $270^\circ$ , then the scalar product (dot product) of these vectors is...
- a) ...positive
  - b) ...negative
  - c) ...undefined
  - d) ...positive when the angle is smaller than  $180^\circ$ , negative when the angle is greater than  $180^\circ$
10. If the scalar product (dot product) of two unit vectors is zero, they are...
- a) ...linearly dependent
  - b) ...forming an orthonormal basis
  - c) ...pointing in the same direction
  - d) ...at an angle of 180 degrees to each other.

11. What is the Euclidean length  $||\vec{v}||$  of vector  $\vec{v} = (0,3,4,0)$ ?

Answer:  $||\vec{v}|| =$  \_\_\_\_\_

12. What is the scalar product (or dot product)  $\vec{v} \cdot \vec{w}$  of the two vectors  $\vec{v} = (0,5,-2)$  and  $\vec{w} = (3,1,-2)$ ?

Answer:  $\vec{v} \cdot \vec{w} =$  \_\_\_\_\_

13. What is the cross product  $\vec{v} \times \vec{w}$  of the two vectors  $\vec{v} = (0,5,-2)$  and  $\vec{w} = (3,1,-2)$ ?

Answer:  $\vec{v} \times \vec{w} =$  \_\_\_\_\_

14. Given vector  $\vec{u} = (2,2)$ , create a unit vector  $\vec{u}'$  that points in the same direction as  $\vec{u}$ .

Answer: \_\_\_\_\_

15. Prove that  $\lambda(-y, x)$  is a normal vector of  $(x, y)$  for all  $\lambda \neq 0$ .

Answer: \_\_\_\_\_

16. If  $y = ax + c$  denotes the *slope-intersect* form of a line in 2D, then  $c$  gives us...

- a) ...the slope of the line
- b) ...the fraction of the slope in the  $x$ -direction
- c) ...the fraction of the slope in the  $y$ -direction
- d) ...the intersection of the line with the  $x$ -axis
- e) ...the intersection of the line with the  $y$ -axis

17. If  $2x - y + 5 = 0$  denotes the *implicit* representation of a line in 2D, then the vector  $(2, -1)$  is...

- a) ...a point on the line
- b) ...a vector parallel to the line
- c) ...a vector perpendicular to the line
- d) none of the above.

18. If  $p(t) = (1,1) + t(-2,1)$  denotes the *parametric* equation of a line in 2D, then  $(1,1)$  is...

- a) ...a point on the line
- b) ...a vector parallel to the line
- c) ...a vector perpendicular to the line
- d) none of the above.

19. The equation  $2x + y + z = 0$  represents...

- a) ...the implicit representation of a line in 3D
- b) ...the implicit representation of a plane in 3D
- c) ...the implicit representation of a line or a plane in 3D
- d) none of the above.

20. In  $\mathbb{R}^3$ , the equation  $(x - 3)^2 + (y - 3)^2 + (z - 3)^2 - 9 = 0$  represents...

- a) ...the implicit representation of a sphere with radius 9 and center  $(3,3,3)$
- b) ...the implicit representation of a sphere with radius 3 and center  $(3,3,3)$
- c) ...the implicit representation of a sphere with radius 9 and center  $(-3, -3, -3)$
- d) ...the implicit representation of a sphere with radius 3 and center  $(-3, -3, -3)$ .

*Good luck!*