

## Comprehensive Exam: Graphics Autumn 2001

**This exam is open book.**

The exam consists of 5 questions. Each question is worth 20 points. Please answer all the questions in the space provided, overflowing onto the back of the page if necessary.

You have 60 minutes to complete the exam.

*The following is a statement of the Stanford University Honor Code:*

- A. *The Honor Code is an undertaking of the students, individually and collectively:
  - 1. that they will not give or receive aid in examinations; that they will not give or receive unpermitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;
  - 2. that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of the Honor Code.*
  
- B. *The faculty on its part manifests its confidence in the honor of its students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code.*
  
- C. *While the faculty alone has the right and obligation to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.*

By writing my "magic number" below, I certify that I acknowledge and accept the Honor Code.

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(Number)

1. [Total: 20 points] Color and intensity.

1A [5 points]. A CRT converts voltage to light intensity. What is the form of the curve used to convert voltage to intensity? If you double the voltage, approximately how much light will be produced?

1B [5 points]. When light enters your eye it creates the sensation of brightness. Suppose you double the amount of light energy entering your eye from a point in the scene, approximately how much will the sensation of brightness change?

1C [5 points]. Are the three color phosphor colors (the so-called R, G and B phosphors) sufficient to generate any color perceivable color? Why or why not?

1D [5 points]. Why do printers use cyan, magenta and yellow inks as their primary colors? In addition, most printing processes use a fourth ink black. Why is using a fourth ink useful?

2. [Total: 20 points] Transformations.

2A [10 points]. Linear transformations may be represented as matrices. An example of a linear transformation is a rotation. A rotation is a special kind of matrix called an orthogonal matrix. An orthogonal matrix has the property that the inverse of the matrix is equal to its transpose. Prove that rotation matrices are orthogonal. Are there other types of matrices that are orthogonal?

2B [10 points]. All non-degenerate transformations (i.e. all except those that map multiple points to the same point) have an associated inverse transformation. Why are inverse transformations useful in computer graphics? Suppose you are given a sequence of transformations, A then B then C then D, what is the inverse of this sequence of transformations?

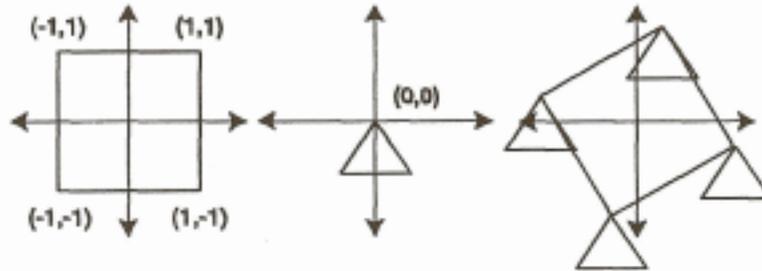
3. [Total: 20 points] Hidden surface elimination.

3A [5 points] Describe the z-buffer algorithm for hidden surface elimination.

3B [15 points] Give three advantages of the z-buffer algorithm over other means for doing hidden surface elimination. Give two disadvantages.

4. [Total: 20 points] Hierarchical modeling.

As part of your new job at Optical Arts, you've been asked to build a simple game with a Ferris wheel. This Ferris wheel is very simple, consisting of a square and a diamond-shaped car for passengers. Assume you have been given two procedures, one to draw a unit square (`square()`) and another to draw a triangular car (`triangle()`). The figures drawn by these procedures are shown below.



Write a graphics program that draws the Ferris wheel at any angle of rotation. Assume the graphics library has transformation commands (the syntax is not important; i.e. make up your own syntax). Make sure that the triangular car is positioned so that its center of gravity is below the point of attachment.

5. [Total: 20 points] Rasterization.

You are building a new graphics library, and you receive a request to write a procedure to draw the following exponential function

$$y^2 = 2^x - 1$$

To simplify the problem, consider only positive  $y$  values. This procedure should draw  $n$  steps along the curve starting at the origin. The procedure should ensure that each point is connected (that is, is adjacent) to the previous point. The procedure should also be written as efficiently as possible. That is, use the minimal number of arithmetic operations in the inner loop. To draw the curve, write down an implicit function that defines the set of points on the curve, and then incrementally trace out the curve. Work out the math, and then fill in the following template:

```
drawexponential(int n)
{
    int x = 0;
    int y = 0;

    for(i=0; i<n; i++) {
        point(x,y);
    }
}
```