

6.837 Introduction to Computer Graphics

Quiz 1: Ray Tracing

Tuesday October 7, 2003 2:40-4pm

One hand-written sheet allowed

Total is 50 points

**Name:**

**1 Ray Tracing [ /14]**

**1.1 Complexity [ /3]**

We want to render a scene of  $N$  objects with one single light source onto an image of  $M$  pixels (the image resolution is  $\sqrt{M} * \sqrt{M}$ ). Any object can be reflective and refractive, but we enforce a maximum recursion depth of  $K$ .

What is the worst-case complexity of ray tracing for the total image?

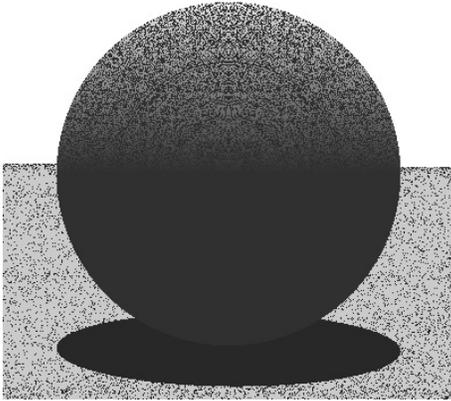
**1.2 Light sources [ /2]**

How is this complexity changed when we have  $L$  light sources?

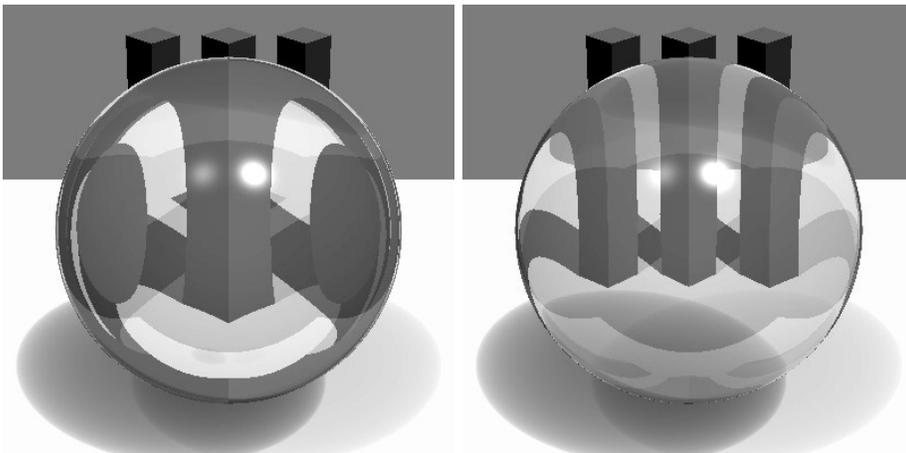
**1.3 Forward ray tracing [ /3]**

Give a 1-to-2-sentence explanation of why forward ray tracing is not directly practical.

1.4 What is the bug that caused the artifacts in this image? [ /3]



1.5 Which sphere has the bigger index of refraction? [ /3]



## 2 Transformations [ /6]

### 2.1 Matrix form [ /3]

What is the  $4 \times 4$  matrix in homogeneous coordinate form corresponding to a 3D translation by  $(a, b, c)$ ?

### 2.2 Normal transform [ /3]

In a ray tracer, when an object is transformed by a linear transformation described by matrix  $M$ , how must we transform the surface normal after ray intersection? Give both a one- or two-sentence explanation and a formula.

## 3 Local shading [ /8]

### 3.1 Coefficients [ /3]

Describe what the image will look like if the scene contains no real light source but the ambient light color is  $(1,1,1)$ .

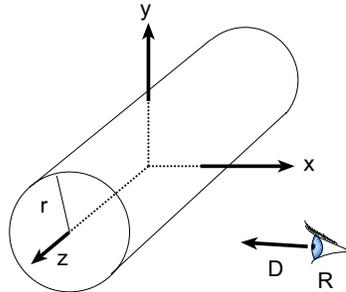
### 3.2 Give a one-sentence description of the Fresnel effect. [ /3]

### 3.3 Dimensionality of BRDFs [ /2]

How many dimensions does an anisotropic BRDF have?

How many dimensions does an isotropic BRDF have?

## 4 Ray-Cylinder Intersection [ /22]



### 4.1 Implicit cylinder [ /2]

Give the implicit equation for an infinite cylinder centered on the  $z$  axis and with radius  $r$ .

### 4.2 Explicit ray [ /2]

Give the explicit (parametric) equation for a ray with origin  $\mathbf{R}$  and direction  $\mathbf{D}$ .

### 4.3 Ray-cylinder intersection equation [ /4]

Write the quadratic equation for the intersection of a ray with an infinite cylinder centered on the  $z$  axis. Solve your equation for  $t$ .

#### 4.4 Ray-cylinder intersection pseudo code [ /8]

Using the result from the previous question, write the pseudocode for the intersection method

```
bool Cylinder::intersect(const Ray &r, Hit &h, float tmin);
```

Don't forget to compute the surface normal, but don't worry about the material.

#### 4.5 General cylinder [ /3]

In your ray tracer, without writing additional code, how would you use the code from question 4.4 to render arbitrary infinite cylinders (arbitrary position and arbitrary orientation)?

#### 4.6 Non-infinite cylinders [ /3]

How would you modify the code from question 4.4 to render non-infinite cylinders. That is, the cylinder only goes from  $z_1$  to  $z_2$ . You do not need to render the caps of the cylinder. You can assume that  $z_2 \geq z_1$ .

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