

## Computer Graphics Ph.D. Qualifying Exam, September 2016

1. (20%) (a) The Phong illumination model can be summarized by the following equation:

$$I = k_e + k_a I_a + \sum_i \left[ I_{l_i} (k_d (\mathbf{N} \cdot \mathbf{L}_i)_+ + k_s (\mathbf{V} \cdot \mathbf{R}_i)_+^{n_s}) \min \left( 1, \frac{1}{a_0 + a_1 d_i + a_2 d_i^2} \right) \right]$$

Draw a diagram to explain the main variables in the above formulation. What effects do the terms of the above formulation intend to model? (b) Describe how to shade a triangle using flat shading, Gouraud shading and Phong shading. Discuss their visual differences.

2. (20%) Given a plane  $\mathbf{n}\mathbf{x} + c = 0$  and a ray  $\mathbf{o} + t\mathbf{d}$ , determine their intersection.
3. (20%) Marching cubes is a famous algorithm for volume rendering. It converts volume data into triangle meshes. (a) For a cell in the volume, how many configurations are there? (b) Draw the generated triangles for the three configurations in Figure 1.

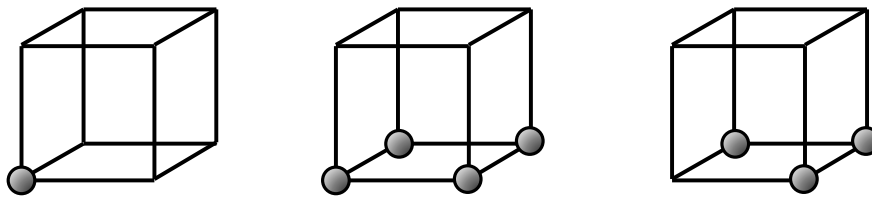


Figure 1: The marching cubes algorithm.

4. (20%) Consider the following equation and diagram in Figure 2:

$$L(x, x') = \delta(x, x') \left[ E(x, x') + \int_S \rho_{x'}(x, x'') L(x', x'') \frac{\cos(\theta') \cos(\theta'')}{\|x' - x''\|^2} dx'' \right]$$

Explain what the terms  $\delta(x, x')$ ,  $E(x, x')$ ,  $S$ ,  $\rho_{x'}(x, x'')$ ,  $\cos(\theta')$  and  $\|x' - x''\|^2$  account for. What is the equation for?

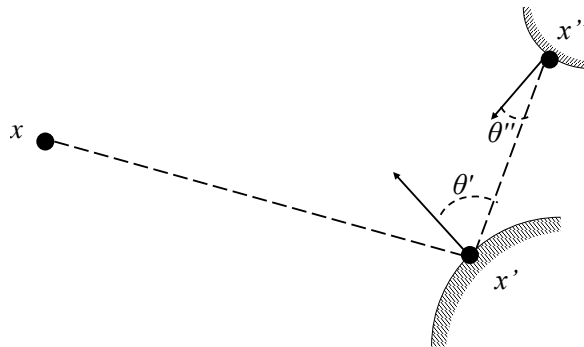


Figure 2: The rendering equation.

5. (20%) Since it is impossible to solve the above equation directly, it is required to make approximations. Describe a method for solving it with approximations. It is fine to make very crude approximations but you need to specify the approximations clearly.