Problem 1: Blinn-Phong Shading [42 points]

The Blinn-Phong shading model for a scene illuminated by global ambient light and a single directional light can be summarized by the following equation:

$$I_{phong} = k_e + k_a I_a + k_d B I_L(\mathbf{N} \cdot \mathbf{L}) + k_s B I_L(\mathbf{N} \cdot \mathbf{H})_+^{n_s}$$

Imagine a scene with one white sphere illuminated by white global ambient light and a single white directional light. For sub-problems (a) – (f), describe – qualitatively, in words – the effect of each step on the shading of the object. At each incremental step, assume that all the preceding steps have been applied first. Assume that the directional light is oriented so that the viewer can see the shading over the surface, including diffuse and specular where appropriate.

(a) (7 points) The directional light is off. How does the shading vary over the surface of the object?

(b) (7 points) Now turn the directional light on. The specular reflection coefficient k_s of the material is zero, and the diffuse reflection coefficient k_d is non-zero. How does the shading vary over the surface of the object?

(c) (7 points) Now translate the sphere straight toward the viewer. What happens to the shading over the object?

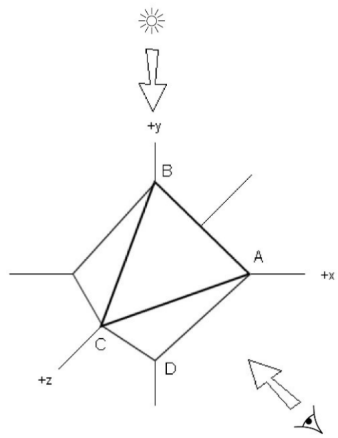
(d) (7 points) Now increase the specular exponent n_s. What happens?

(e) (7 points) Now increase the specular reflection coefficient k_s of the material to be greater than zero. What happens?

(f) (7 points) Now decrease the specular exponent n_s. What happens?

Problem 2: Interpolated Shading [58 points]

The faceted polyhedron shown below is an octahedron and consists of two pyramids connected at the base comprised of a total of 8 equilateral triangular faces with vertices at (1,0,0), (0,1,0), (0,0,1), (-1,0,0), (0,-1,0), and (0,0,-1). The viewer is at infinity looking in the (-1,0,-1) direction, and the scene is lit by directional light shining down from above parallel to the y-axis with intensity I_L = (1,1,1).



The octahedron's materials have both diffuse and specular components, but no ambient or emissive components. The Blinn-Phong shading equation thus reduces to:

$$I = I_L B \left[k_d(\mathbf{N} \cdot \mathbf{L}) + k_s(\mathbf{N} \cdot \mathbf{H})_+^{n_s}\right]$$

where

$$B = \begin{cases} 1 & \text{if } \mathbf{N} \cdot \mathbf{L} > 0 \\ 0 & \text{if } \mathbf{N} \cdot \mathbf{L} \leq 0 \end{cases}$$

For this problem, $k_d = k_s = (0.5, 0.5, 0.5)$ and $n_s = 40$.

Hint: if directional light is a model of light where its point of origin is infinitely far away, what would a viewer at infinity imply for the viewing direction?

(a) (8 points) In order to draw the faces as flat-shaded triangles, we must shade them using only their face normals. In OpenGL, this could be accomplished by specifying the vertex normals as equal to the face normals. (The same vertex would get specified multiple times, once per triangle with the same coordinates but different normal each time.) What is the unit normal for triangle ABC?

(b) (10 points) Assume that this object is really just a crude approximation of a sphere (e.g., perhaps you are using the octahedron to represent the sphere because your graphics card is slow). If you want to shade the octahedron so that it approximates the shading of a sphere, what would you specify as the unit normal at each vertex of triangle ABC?

(c) (20 points) Given the normals in (b), compute the rendered colors of vertices A, B, and C. Show your work.

(d) (10 points) Again given the normals in (b), describe the appearance of triangle ABC as seen by the viewer using Gouraud interpolation.

(e) (10 points) Now switch from Gouraud-interpolated shading to Phong-interpolated shading. How will the appearance of triangle ABC change (given the normals in (b))?