Assignment 1b: Light and Shadow **Due Date: Weds Oct. 2, 2019**

In this assignment, you are asked to:

- Extend the ray casting program that you wrote for assignment 1a to:
    a. Allow the color at each rendered ray/surface intersection point to be defined using the Blinn-Phong illumination model with one or more directional and/or point light sources, rather than simply returning a constant default color for every ray/surface intersection point; and
    b. Model the effect of cast shadows, by tracing a secondary ray from the ray/surface intersection point at which the shading is being computed towards the light source(s) and checking for potential intersections with intervening objects along the way
- Explore the effects of the various parameters in the Phong illumination model and demonstrate the lighting and shadowing capabilities of your program by running it on a variety of different input files, featuring a variety of different illumination settings.

If you would like to earn extra credit, there are three options, each worth an additional 4%:

- Enable your raytracer to generate "soft" shadows by tracing a bundle of secondary rays towards the light source(s), and computing a non-binary shadowing factor rather than using just one ray to set a binary shadow flag;
- Implement spotlights, defined by a position, direction, and angle across which the light source shines; be sure that the shadows cast by your spotlights are handled correctly
- Implement light source attenuation, enabling the intensity of the illumination from a point light source to fall off with distance

Detailed instructions:

- The Phong illumination equation defines the color of an object at a point as a function of the material properties of the surface and the orientation of the surface with respect to the viewer and with respect to any light sources. This means that in order to use the Phong illumination equation, you will need to allow the user to specify not only the intrinsic color of the object (now referred to as the object's diffuse color), but also its reflectivity (via the ambient, diffuse and specular coefficients and the specular exponent). You will also need to allow the user to specify a color for the specular highlight. Please use the following syntax for this:

mtlcolor *Od_r Od_g Od_b Os_r Os_g Os_b ka kd ks n*

- A point light source is defined by a 3D location in space $(x, y, z, 1)$, and a directional light source is defined by a vector $(x, y, z, 0)$. In order to use the Phong illumination model, you will need to extend your scene description file to allow the specification of one or more light sources. Using a value less than (1, 1, 1) for the light color is recommended when the scene contains multiple light sources. Using different-values for the three components will result in a colored light, which will affect the hue as well as the brightness of the surfaces it hits. Please use the following syntax to define your light sources:

  light *x y z w r g b*

  If you wish to define spotlights, please use a different keyword:

  spotlight *x y z dir_x dir_y dir_z theta r g b*

  If you wish to implement light source attenuation, please use the syntax:

  attlight *x y z w r g b c_1 c_2 c_3*

  attspotlight *x y z dir_x dir_y dir_z theta r g b c_1 c_2 c_3*

- The program you wrote for assignment 1a should use a function *ShadeRay* to retrieve the color of the closest object that is hit by each ray extending forward from the eye position. For the current assignment, you will need to extend this *ShadeRay* function to calculate the color appearance at each point as a function of: the intrinsic color of the surface and other relevant properties of the surface material, and the orientation of the surface with respect to the light source(s) and the eye position, using the Blinn-Phong illumination equation.

- To determine whether a ray/surface intersection point is in shadow, you will need to cast a secondary ray from the ray/surface intersection point toward each light source in your scene and check to see if it intersects any other object along the way. If the "line of sight" from the light source to the surface point is clear of any obstruction, the point will not be in shadow. Be sure to only consider obstructions from objects that are *between* the light and the surface; any objects that might be behind a point light source, with respect to the surface, would not block the light from arriving to it. You can implement shadows by incorporating a shadow flag, for each light source, into your illumination calculations. For the basic assignment, the shadow flag should be initialized with a value of 1 and then take on a value of 0 if it is determined that incident energy from the light is blocked from reaching the surface. For the extra credit extension, a bundle of rays should be used to obtain multiple shadow values (each 1 or 0) and the average of those values should be used to define the value of the shadow flag for each light source. Later on we will extend the shadow functionality to enable partial shadowing by transparent objects.

- To explore the impact of the illumination parameters on the appearance of the rendered scene, you should run your program on multiple input scene files whose parameter settings differ in carefully controlled ways. You are advised to begin by varying the values of just one parameter at a time. Once you understand the effect of each parameter in isolation, you can experiment with combinations of changes.

What you should turn in:

A single .zip file containing:

- all of your source code, clearly commented, along with a Makefile that we can use to compile your code
- An original input scene description and accompanying output image that shows off the capabilities of your program. Please try to be creative!
- A 2-3 page writeup, illustrated with images produced by your program, in which you discuss how each of the illumination model parameters affects the appearance of the rendered scene. Please be sure to consider:
    - the effects of: k_a, k_d, k_s, n and $O_{s\lambda}$ in addition to $O_{d\lambda}$
    - the use of a directional light source vs a point light source
    - the use of multiple lights vs a single light

  In addition, if you have done any of the extra credit parts, please be sure to include that in your writeup, along with images showing the success of those implementations.

CSci 5607, Fall 2019
Assignment 1b: Light and Shadow
Due: Wednesday Oct 2nd

Name ______________________________

Score (out of 100) __________________

____ The required files were submitted in the requested format: a single .zip file, including a Makefile along with the source code for easy compiling. The program is well-commented and structurally sound. It does not 'bomb' in response to reasonable unanticipated input. (5 pts)

____ The program correctly accepts extended scene information, including expanded material properties ($Od\lambda$, $Os\lambda$, k_a, k_d, k_s, and n), and multiple point light sources and/or directional light sources with associated wavelength-dependent intensity information. (5 pts)

____ In a scene with one or more spheres and a single directional light source, the program will correctly determine the surface illumination at each ray/surface intersection point where a surface color needs to be computed, using the Blinn-Phong illumination equation provided in class. All necessary vectors are properly computed, including: the surface normal direction, the direction to the light source, the direction to the viewer, and the direction of the 'halfway' vector between the direction to the viewer and the direction to the light source. (10 pts)

____ In a scene with one or more spheres and a single point light source, the program will correctly determine the surface illumination at each ray/surface intersection point where a surface color needs to be computed, using the Blinn-Phong illumination equation provided in class. (10 pts)

____ In a scene with one or more spheres and multiple light sources, the program will correctly determine the surface illumination at each ray/surface intersection point where a surface color needs to be computed, using the Blinn-Phong illumination equation provided in class. Intensity overflow errors are explicitly avoided. (15 pts)

____ In a scene containing multiple spheres and a single directional light source, the program will correctly determine whether or not a ray/surface intersection point is in shadow. (10 pts)

____ In a scene containing multiple spheres and a single point light source, the program will correctly determine whether or not a ray/surface intersection point is in shadow. The program does not incorrectly cast shadows from objects that are behind the light source. (10 pts)

____ In a scene containing multiple spheres and multiple light sources, the program will correctly determine whether or not a ray/surface intersection point is in shadow. (15 pts)

____ The student has submitted at least one original scene file, along with a corresponding output image produced by his or her program. The submitted image adequately demonstrates the capabilities of the program. (5 pts)

____ The student has submitted a 2-3 page write-up in which they both discuss and demonstrate, using appropriately-derived example images created by their program:

- the effects of: k_a, k_d, k_s, n and $O_{s\lambda}$ in addition to $O_{d\lambda}$
- the effects of using a directional light source vs a point light source
- the effects of using multiple lights vs a single light

The write up specifically discusses how the use of different light source types and light source parameters affects the results as well as how each of the different material properties in the Blinn-Phong illumination model affects the surface appearance. (15 pts)

For extra credit:

____ The student's program is capable of rending "soft" as well as hard shadows. The student has provided an input scene description that allows this effect to be appreciated, and the effectiveness of their solution can be seen in the corresponding output image produced by their program. The program uses an appropriate number of samples to avoid artifacts. (4 pts)

____ The student's program is capable of implementing spotlights as well as point and directional light sources. The student has provided an input scene description that allows this effect to be appreciated, and the success of their implementation can be seen in the corresponding output image produced by their program. (4 pts)

____ The student's program is capable of implementing attenuated light sources. The student has provided an input scene description that allows this effect to be appreciated, and the success of their implementation can be seen in the corresponding output image produced by their program. (4 pts)