Name: ________________________________

Homework 2

15-462/15-662 Computer Graphics, Spring 2013
Due 4/23 at the beginning of class

85 points
Please show all of your work.
Even if you work things out in your head, write it down so we can see what you are doing.
Please list any references that you used to research or obtain your solution.

Part 1. The rendering equation from James Kajiya's 1986 SIGGRAPH paper is as follows:

$$\boldsymbol{I(x,x') = g(x,x')\left[\epsilon(x,x') + \int_S \rho(x,x',x'')\, I(x',x'')\, dx''\right]}$$

1. **(5 points)** Draw a diagram illustrating transport of light in a simple scene and label it with terms used in this equation.

2. **(10 points)** In plain language, describe the meaning of the following terms or symbols:
   a. $g(x,x')$
   b. $\epsilon(x,x')$
   c. $\int_S$
   d. $\rho(x,x',x'')$
   e. $I(x',x'')$

3. **(5 points)** Now, assume that you are considering **Ray Casting** only. Consider a single ray from the eye through a pixel center to the first object it intersects. You may assume this ray does not directly strike a light source. You may also assume point light sources. The Phong Illumination model will be used to determine the color of the pixel. Sketch this scenario.

4. **(10 points)** The rendering equation can be applied to the scenario described in Question 3. Label your diagram with the points x, x', and x'' and describe as precisely as possible what will be the value of the following terms or symbols:
   a. $g(x,x')$
   b. $\epsilon(x,x')$
   c. $\int_S$
   d. $\rho(x,x',x'')$
   e. $I(x',x'')$

5. **(5 points)** Now, assume that we are trying to solve for the **Radiosity** of various surface patches in an environment. You may now assume that x, x', and x'' are no longer points, but are surface patches. Sketch this situation.

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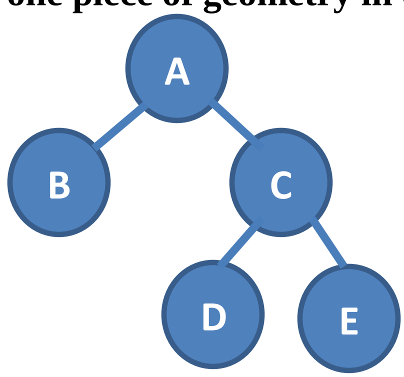
6. **(10 points)** The rendering equation can be applied to this scenario as well. Describe as precisely as possible what will be the value of the following terms or symbols for the scenario described in Question 5.
   a. $g(x, x')$
   b. $\epsilon(x, x')$
   c. $\int_S$
   d. $\rho(x, x', x'')$
   e. $I(x', x'')$

7. **(5 points)** Using your answers to Question 6, rearrange the rendering equation to obtain the power equation for radiosity as presented in the slides in class. Show your work. The power equation is as follows:

$$\Phi(x) = \Phi_e(x) + \rho(x) \sum_{x'} \Phi(x')\, F(x' \to x)$$

Part 2. You are given a binary search tree which is a hierarchical data structure representing your scene. You may assume that branches to the right side are closer to the eye than branches to the left side. You may also assume there is only one piece of geometry in every leaf node.



8. **(5 points)** If this tree represents a bounding sphere hierarchy, what is the search order for the tree? Please be efficient in the sense of checking areas closest to the eye first.

9. **(5 points)** If this tree represents a bounding sphere hierarchy, when should the search be terminated?

10. **(5 points)** If this tree represents a BSP tree, what is the search order for the tree? Please be efficient in the sense of checking areas closest to the eye first.

11. **(5 points)** If this tree represents a BSP tree, when should the search be terminated?

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Part 3. Separating Direct and Indirect illumination. Refer to the following paper discussed in class:

Nayar, Shree K., Gurunandan Krishnan, Michael D. Grossberg, and Ramesh Raskar. "Fast separation of direct and global components of a scene using high frequency illumination." *ACM Transactions on Graphics (TOG)* 25, no. 3 (2006): 935-944.

12. **(15 points)** Please describe concisely the main idea behind how we can separate out direct from indirect illumination from real-world scenes. You may use diagrams and/or equations to explain your point if you wish, but your explanation should be clear even to someone who has not read the paper or attended class.