## Stanford CS248A: Computer Graphics <br> Participation Exercise 5

This exercise is graded for CREDIT ONLY. Serious attempts to answer the problems will be given full credit, even if the answers are incorrect.

## Problem 1: Making Sure You Understand Bounding Volume Hierarchies

A. Consider the scene below organized into a BVH. The structure of the BVH is shown in the top-right. Please give the ordered sequence of BVH nodes that the ray must visit when determining the closest intersection along the ray. You should assume that: (1) when a ray hits both child bounding boxes of the current node, the ray will recurse into the node with the closest bounding box first, (2) If a ray has already found an intersection that is closer than one of the child bounding boxes of the current node, it will skip visiting that node.

B. Now consider the same scene, but now with a light source, represented by the yellow star, shown below. Consider the task of computing if a point $P_{0}$ is in shadow. Recall that the point is in shadow if a ray from the light toward $P_{0}$ hits something before reaching $P_{0}$ or, equivalently, if a ray from $P_{0}$ towards the light hits something before reaching the light. As an example, a shadow ray traced toward the light source is shown in the picture. Unlike part A, where we asked you to reason about the behavior of tracing a ray that found THE CLOSEST HIT in the scene, when tracing a shadow ray we only need to determine if there is ANY HIT with a scene object between $P_{0}$ and the $P_{1}$ (the point on the light). Given this shadow query and this scene, would you rather trace a ray from $P_{0}$ in the direction of $P_{1}$, or from $P_{1}$ in the direction of $P_{0}$. Why?
Hint: Consider the efficiency of both approaches.


## Problem 2: Everyone Loves Lasers

A mad scientist decides to design a fun physics experiment to amuse students in class. The goal of the experiment is to use two perfectly reflective mirrors to direct a laser beam, positioned downward from the top of the box, to hit a target in the bottom right corner of the box. The two mirrors can be rotated about their center point by the angles $\theta_{1}$ and $\theta_{2}$ as shown in the figure.

A. Please compute positive values of $\theta_{1}$ and $\theta_{2}$ to hit the box. Some helpful triangles are given for you, which may or may not be useful. Hint: first determine how to orient the first mirror to direct the beam to hit the second mirror. Then orient the second mirror to hit the target. Please review the slides from lecture about perfect specular reflection.
B. One challenge with perfect mirrors is that if you don't get them tilted just right, the laser will miss the target. One of the students, frustrated they couldn't hit the target, takes out a piece of sandpaper and scruffs up the two mirrors. The result is that the mirrors now have a BRDF that is almost fully diffuse, as given by the plot below. Note the surface reflects non-zero incoming light in all directions, but the fraction of light reflected in each of these directions is angle dependent. (More light is still reflected in the direction of perfect specular reflection.)


Assuming that (1) the mirrors are set so that $\theta_{1}=\theta_{2}=0$ and that all the walls of the room reflect no light (they are perfectly black), does any laser light hit the target? If your answer is no, explain why not. If your answer is yes, please explain why, and also state whether target is brighter or darker compared to what it would look like in the case of well-aligned perfect mirrors from part A.

## OPTIONAL PROBLEM 3: Reasoning about BRDFs (NOT REQUIRED FOR CREDIT)

A. Consider the following setup where a red laser (a point light source emitting light in a single direction) is shining on sphere that is a perfectly reflective mirror surface. The light reflects off the sphere directly into the eyes of a person standing in the room. Assuming that there no other light sources in the room, and all other surfaces of the room are black, what does the person see if they lower the position of their head by sitting on the floor? Why? (Hint: a good answer will refer to the amount of light arriving at the viewer's eyes.)

B. A mysterious floor material. You are standing in a room with a floor that is completely flat, but covered with two different types of materials (denoted as 1 and 2 in the figure below). The room only has one light source, a far away point light that is directly above the floor, and shines light directly down on the floor. (You can think of it as a very, very narrow spotlight, shining straight down.) Material 1 has a completely diffuse BRDF (white material) and Material 2 is a perfect mirror that reflects all light that hits it. If you are standing on the side of the floor at point $P$ (as shown in the figure) what do you see? In particular be precise about what the mirror tiles look like. (Can you see anything in them, yes or no?) Remember, there is no other light source in the room other than the spotlight from above..

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| 1 | 2 | 1 | 2 |
| 2 | 1 | 2 | 1 |
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