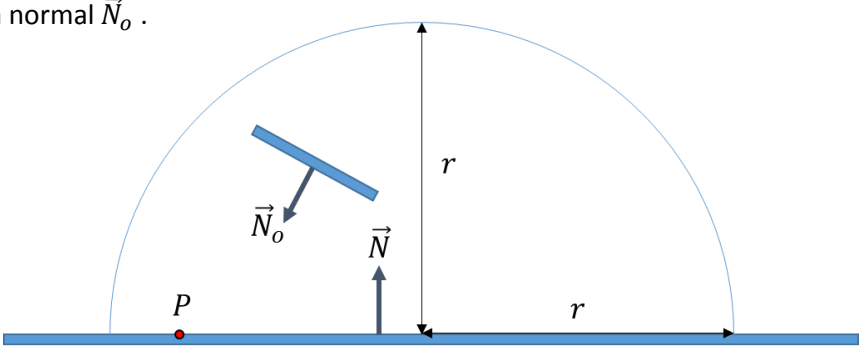
ADVANCED GRAPHICS – 2016/2017

February 2nd – 17.00 – 19.00 – RUPPERT-BLAUW

Please write clearly. Please do not ask for clarification during the exam. If you find a question unclear or ambiguous: write down how you interpret the question, then answer it. You can score up to 100 points. Your grade is: `max(1,pts/10)`.

IMPORTANCE

1. Consider a scene consisting of three objects (see figure):
   - an infinite horizontal plane with normal $\vec{N}$;
   - a hemispherical non-reflective skydome with radius r, casting uniform illumination inwards;
   - a single planar occluder with normal $\vec{N}_o$.



Answer the following questions about this situation. Do not consider indirect light.

   a) Do we need to know r to calculate the irradiance arriving at a point P on the plane inside the dome? Why / why not? *(5 pts)*

   b) How would you importance sample this setup? Take the occluder into account. *(10 pts)*

   c) We now remove the occluder. The dome emits a total of 100W. What is the irradiance arriving at P? Explain your answer. *(5 pts)*

2. Explain why the following techniques can be seen as importance sampling techniques:

   a) Next Event Estimation *(5 pts)*

   b) Russian Roulette *(5 pts)*

   c) For dielectrics: basing the probability of generating a reflection on the Fresnel term *(5 pts)*

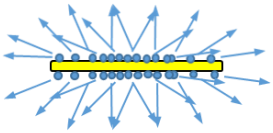
ACCELERATION STRUCTURES

3. Regarding the Surface Area Heuristic:

   a) Explain why the SAH produces better BVHs than midpoint splitting. *(10 pts)*

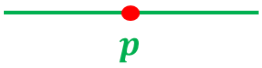
   b) The Surface Area Heuristic is a simplified cost model. Explain what factors are not taken into account. *(Note: you may have encountered this in a paper, but this is not intended as a knowledge probe; I'm asking you to reason about this.) (10 pts)*

LIGHT TRANSPORT



4. A scene is illuminated by a single double-sided square light source. Two algorithms are used to sample the light source: the first picks a random point on a random side of the light source, while the second algorithm only picks random points on the side of the light source facing the point we want to shade (point $\boldsymbol{p}$).

   Show, using the mathematical formulation of Monte Carlo integration, that both methods yield the same result when using an infinite number of samples. *(15 pts)*



GPU RAY TRACING

5. What problem does Wavefront Path Tracing (as described in "Megakernels Considered Harmfull") aim to solve? *(10 pts)*

6. Explain how a kD-tree can be traversed without using a stack, without adding data to the nodes (so, no ropes, no short stack). *(10 pts)*

BRDFS

7. The Phong illumination model, without ambient factor, can be formulated as follows:

$$I_x = \sum_{m \in lights} \left(k \left(\underline{\vec{N} \cdot \vec{L}_m} \right) + k \left(\underline{\vec{R}_m \cdot \vec{V}} \right)^{exponent} \right) I_m$$

where k is the material color, $\vec{L}_m$ is a unit vector to light m, $\vec{R}_m$ is vector $\vec{L}_m$ reflected in the surface normal $\vec{N}$ and I_m is the luminance of light m. Underlining of dot products denotes clamping to zero.

a) The model does not ensure energy preservation. This is far less of an issue in Whitted-style ray tracing than in a path tracer. Why? *(5 pts)*

The Modified Phong BRDF is based on the Phong illumination model. It is defined as:

$$f_r(x, \theta_i, \theta_o) = k\frac{1}{\pi} + k\frac{exponent + 2}{2\pi} cos^{exponent} \varphi$$

b) This BRDF does not obey the Helmholtz reciprocity. Why not? *(5 pts)*

May the Light be with you!