ECE 595 / CS 491 / CS591 Real-time Rendering and Graphics Hardware, Spring 2007

Final Exam

This is a *take-home* final exam. This means that you can use books, notes and online resources to help you answer these questions. However, you cannot ask others for help, whether in person or online. **You are to answer all the questions on your own.** The exam will be released to you on Monday May 7 and you are to turn it in Thursday May 10 by 11:59pm. You can either email me your exam or slip it under my door by this time.

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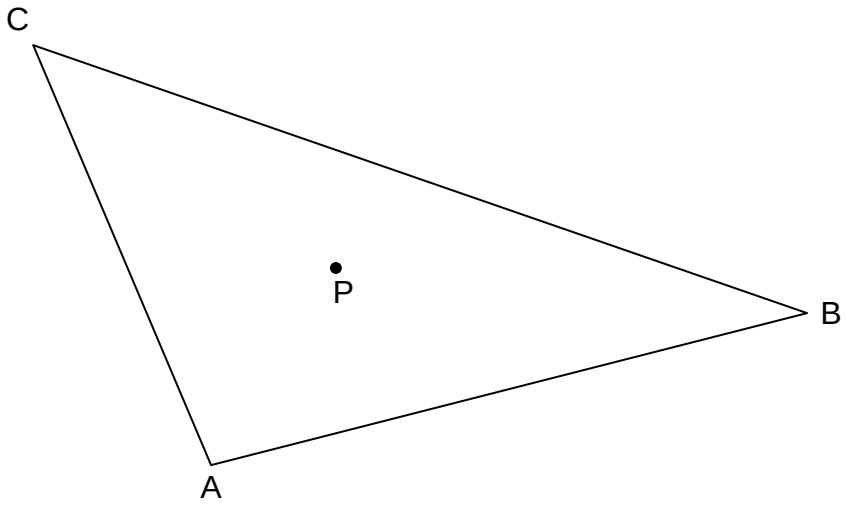
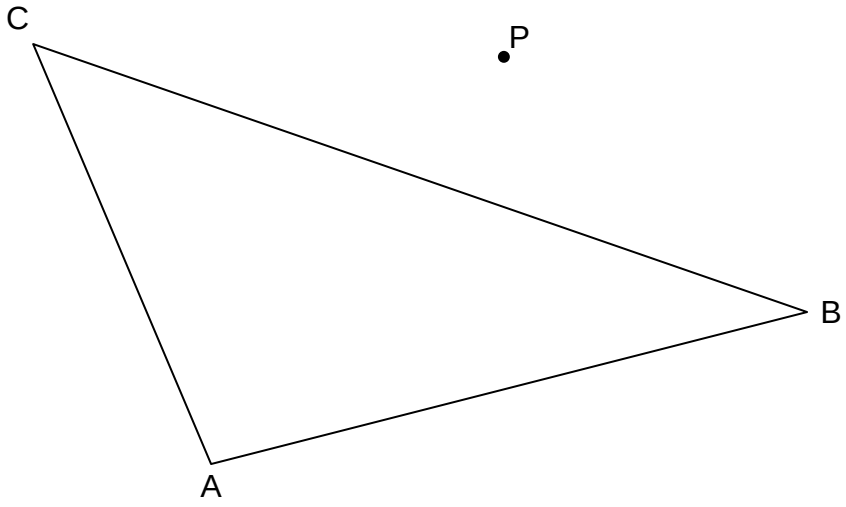
Name

1. **[10]** Derive the complete perspective projection transformation matrix. Assume that (as in OpenGL), the frustum is defined in *x* by the left plane *l* and the right plane *r*, in the *y* axis by the bottom plane *b* and the top plane *t*, and in the *z* axis by the near plane *n* and the far plane *f*. Assume that n and f are defined as the positive distance to the near and far plane, even though they are located in –z. Unlike OpenGL, set up the transformation so that it transforms the frustum to the cubic volume which ranges from –*c* to *c* on each axis.

2. **[5]** Given the triangle below and the point P, show geometrically how you would compute the barycentric coordinates (α, β, γ) for the given point **[4]**. Remember that the barycentric coordinates would interpolate the values at vertices A, B, C at point P as $\alpha A + \beta B + \gamma C$. **[1]** What is $\alpha + \beta + \gamma$ equal to?



3. **[5]** What if point P where to be moved outside the triangle, as shown below. How do you compute the barycentric coordinates of P **[3]**? Show the triangles involved clearly, perhaps by using different hatching pattern for each area. **[1]** What is the sum $\alpha + \beta + \gamma$ equal to now? **[1]** How have the signs of α, β, γ changed?



4. **[5]** Write a fragment program to texture a quad with 3 concentric circles. The largest should be red (1,0,0) and its diameter should be equal to the size of the quad. The smaller circles should be green (0,1,0) and blue (0, 0, 1) and each should be half the diameter of the previous. You can do it in either Cg or ARB_fragment_program.

5. **[5]** Write a fragment program to draw a black and white checkerboard pattern of size 10. You can do it in either Cg or ARB_fragment_program.

6. **[5]** Define the following terms and provide their units:
    1. radiance

    2. irradiance

    3. intensity

    4. BRDF

    5. power

7. **[2]** True/False. Radiance falls off by $1/r^2$ along a ray in free space.

8. **[5]** What is the difference between the BSSRDF and the BRDF?

9. **[5]** How are the BRDF's of real surfaces measured?

10. **[5]** How are BRDF's typically parameterized (e.g. what is their dimensionality, etc)?

11. **[5]** What are isotropic BRDF's? How many dimensions do you need to parameterize them?

12. **[3]** What are the properties of a Lambertian surface?

13. **[5]** What is the classic reflection equation that turns incident radiance into outgoing radiance? Explain the terms of the equation

14. **[5]** The diffuse lighting term is often written as N dot L. Why is there a dot product? What does it do?

15. **[5]** Describe how the smoothies algorithm by Chan and Durand creates soft shadows. Draw pictures if it helps explain their algorithm.

16. **[5]** What causes soft shadows? Draw a configuration in 2-D with occluders and receivers and point out the penumbra and the umbra.

17. **[5]** Define the term “global illumination.” Why does it make a difference in real-time rendering? Give three examples of global illumination effects that we would like to see in games.

18. **[5]** A lot of the papers assume distant illumination. What does that mean? What properties does distant illumination have?

19. **[5]** Describe how you use a direction vector <x, y, z> to index into a cubemap.

20. **[5]** What are irradiance maps? For what kinds of surfaces are they used?

21. **[5]** What do we mean by the term “pixel basis” ? Show how you would decompose a bitmapped image in the pixel basis?

22. **[5]** What is LOD and why is it important in games? Discuss an algorithm to do LOD and describe how it works.

23. **[5]** Why would you want procedural terrain in a game?

24. **[5]** What kinds of procedural systems are often used to automatically create plants? How do they work?

25. **[5]** Why is there a need to ping-pong textures in many GPGPU applications? When do we need to do this?

26. **[10]** In GPGPU, people are always talking about algorithms that are either “scatter” or “gather.” What do these terms mean? Which one is easier to implement on graphics hardware? How would you impement the other on a GPU?

27. **[5]** Suppose your scene consisted of a mirror sphere inside a known environment represented by an environment map. How would you render the reflection if you were using a scanline renderer? And if you were using a ray tracer?

28. **[5]** How do ray-tracers generate hard shadows? How do they generate soft shadows?

29. **[5]** What are the advantages and disadvantages of a uniform grid structure for accelerating ray tracing? Draw a scene where it would fail.

30. **[20]** Write a brief summary of one of the three following papers:

Ravi Ramamoorthi and Pat Hanrahan "An Efficient Representation for Irradiance Environment Maps." SIGGRAPH 2001

Peter-Pike Sloan, Jan Kautz and John Snyder "Precomputed Radiance Transfer for Real-time Rendering in Dynamic Low-Frequency Lighting Envronments." SIGGRAPH 2002

Ren Ng, Ravi Ramamoorthi, and Pat Hanrahan. "All-Frequency Shadows Using Non-Linear Wavelet Lighting Approximation" SIGGRAPH 2003

Select one of these papers and write a few paragraphs about it. Describe what the problem is the authors are trying to solve and how they go about solving it. What are some of their observations that make this possible? Be as specific as possible. Feel free to download these papers and read through them to help you answer this question!