Notes on final exam. Wednesday, December 18, 12:00 - 2:00 in Carver 32.
Exam is optional. If you want to try it but do poorly, it won't count against you.

Comprehensive written test, similar in format to midterm, time limit 120 minutes. See the midterm exam review sheet for topics up until midterm.

Texture mapping
Texture coordinate space

Suppose the rectangle below (two triangles) has texture coordinates (0, 0) at A, (1, 0) at B, (0.5, 1) at C, and (0, 1) at D. Sketch what the 2 x 2 checkerboard texture looks like when mapped to that quad.

```
A ----- C
|     /|
|    / |
|   /  |
|  /   |
| /    |
D-----B
```

Image formats (RGB, RGBA, ...), loading pixels
Issues
1. How to determine texture coordinates
2. How to sample from a texture
3. How to use the sampled value
Wrapping options (repeat, clamp)
Filtering options – nearest, linear
Sampling and antialiasing concepts, nearest vs linear filtering
- Show/draw/explain how linear filtering works
- Why does a texture tend to look blurred with linear filtering?
Minification, magnification, mipmaps
- What artifacts do you typically see as a result of magnification?
- What is the purpose of mipmaps?
Mipmapping options – nearest/nearest, nearest/linear, linear/nearest, linear/linear
- Explain in words what these mean
Using texture value (replace, modulate, blend)
- Write a fragment shader that uses the texture value to modulate the intensity of the specular highlight

Procedural textures
- Write a fragment shader that generates a 2 x 2 checkerboard pattern (assume you have an in variable representing the texture coordinate)

Bump mapping
Normal maps
  How are normal vectors encoded into a texture as RGB?
  Why do normal maps typically look blue?

Height maps
  Explain in pseudocode how you’d convert a height map to normal map

Tangent (local) coordinates
  Why do we need local coordinates?

Using the inverse TBN matrix
  Assuming you are given normal and tangent vectors for each vertex, write a shader pair for doing bump mapping. You can assume that the given normal and tangent are orthogonal and normalized. (Assume you can cut and paste the the usual Phong lighting calculation from an existing fragment shader.)
  a) Set it up to do the lighting calculation in "local" coordinates.
  b) Set it up to do the lighting calculation in eye coordinates. Why is this likely to be less efficient?

Cube maps, sampling from an OpenGL cube texture
  Suppose you have a model that doesn’t have texture coordinates. Show how you could apply any texture to the model using the idea of cube mapping. Assume the model’s center is at the origin.

Reflection (environment mapping) using cube map

Framebuffer objects, attachment points
Rendering to a texture
  Implement a “scene within a scene”, i.e., an image of the scene itself appears on a quad within the scene

Shadow mapping
  Explain, in words and a sketch, what steps are involved.
Concept of a matrix stack

Hierarchical models

Give an example of a hierarchical model based on one type of primitive solid (sphere, cylinder, etc.). Write down the stack operations you’d use to render it, assuming that the top matrix on the stack is always used as the model matrix.

Perlin noise (Gradient noise)

Suppose you have two textures; texture unit 0 is bound to an image texture and texture unit 2 is bound to a 2D texture containing noise values in \([-1, 1]\) stored as values \([0, 1]\) in the red channel. Write a fragment shader that uses noise to modulate the transparency of the first texture before applying lighting.

Write a fragment shader that uses a 3D noise texture to modulate the surface color between red and yellow.

Geometry shaders

Where does a geometry shader fit in the overall OpenGL pipeline?

Billboarding

What is it for?

view plane aligned

view point aligned

Given the view matrix along with the up direction for world coordinates, derive the transformation for a view point aligned billboard a) preserving the world up direction, b) not preserving the world up direction