This exam contains 8 pages (including this cover page) and 4 questions.
Total of points is 60.

- Don't spend too much time on any one problem.

  This exam should take approximately 50 minutes.

- Note that the amount of points may vary per question.

- Be neat.

- Show how you got your answers! Answers with no work will receive zero points.

- Write down your assumptions.

- Access to one sheet of hand-written notes and a calculator is allowed.

  Regardless of whether you have a calculator, you must write the arithmetic expression which produces the answer.

  Feel free to leave unsimplified fractions and square roots in your answer.

- If multiple answers are given to a question, I will grade the lower-rightmost one.

Grade Table

Question	Points	Score
Graphics Pipeline (short answer)	20	
Shading	20	
Camera Transforms	20	
Extra Credit	0	
Total:	60	

1. 20 points **Graphics Pipeline (short answer)**

Please answer the following multiple-choice questions about the graphics pipeline:

(a) 2 points Specular shading should change as you move your camera around to look at the (specularly reflected) object from different angles.
  ○ True
  ○ False

(b) 2 points In Gouraud shading, normals are interpolated across rasterized primitives so that lighting can be computed on a per-fragment basis.
  ○ True
  ○ False

(c) 2 points In deferred shading, transparent objects are easier to render but not as many light sources can be used.
  ○ True
  ○ False

(d) 2 points The contents of a renderbuffer can be attached to a framebuffer but not accessed from a shader.
  ○ True
  ○ False

(e) 2 points Using orthographic projection, the z-buffer is not necessary because objects appear the same 'depth' regardless of where they are in the scene.
  ○ True
  ○ False

(f) 2 points If a framebuffer is bound while drawing an object that is textured with one of the framebuffer's attachments, simultaneously reading and writing to that framebuffer is possible.
  ○ True
  ○ False

(g) 2 points The model matrix is used to transform coordinates from object space into world space.

○ True

○ False

(h) 2 points Given a texture with a different color per texel, when mapped onto a sphere, some fragments of the sphere may share the same color.

○ True

○ False

(i) 4 points Given an application defined geometric object (say a tree) that is specified in world coordinates as being 2 units tall and is 10 units away from the camera and a view plane that is 1 units away from the camera, how tall will the tree be using perspective projection:

  A. 0.4 unit

  B. 0.2 unit

  C. 5.0 unit

  D. not enough information to determine

2. 20 points **Shading**

Given a light with the following $\{r, g, b\}$ ambient, diffuse and specular terms:

light_color $= \{1, 1, 1\}$

and a material with the following ambient, diffuse and specular terms:

material_ambient $= \{0.1, 0.1, 0.1\}$

material_diffuse $= \{0.6, 0.6, 0.8\}$

material_specular $= \{0.4, 0.4, 0.0\}$

material_shininess $= \{2\}$

For a point located at $\{3, 5, 10\}$ with the normal is $\{1, 2, 2\}$ and the camera is located at $\{4, 9, 18\}$, and assuming that the light is located at is $\{7, 1, 3\}$, what is the reflected color $\{r, g, b\}$, computed using the Blinn-Phong model (i.e. use the half vector H, not the computation involving V and R for the specular)?

(Assume there is no distance attenuation).

Show your work!

Extra space for work/answer.

3. 20 points **Camera Transforms**

Given the following glm call:

`LookAt(vec3(4, 0, 3), vec3(3, 4, 11), vec3(0, 1, 0))`

where the function prototype is:

`LookAt(eye, target, up)`

(a) 6 points What are the $\{u, v, w\}$ (camera basis vectors) for this setting?

(b) 4 points What is the camera transform (please write it as two matrices, the translation and rotation, not as a single composite matrix):

Recall that:

$$
\begin{bmatrix}
u_x & u_y & u_z & 0 \\
v_x & v_y & v_z & 0 \\
w_x & w_y & w_z & 0 \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
1 & 0 & 0 & -e_x \\
0 & 1 & 0 & -e_y \\
0 & 0 & 1 & -e_z \\
0 & 0 & 0 & 1
\end{bmatrix}
$$

(c) 6 points What are the coordinates of the point in the world $\{0, 0, -2\}$ in the camera space?

(d) 4 points If you had WASD keys enabled, and the user hit the d key and wanted to move forward (one unit), what are the updated values sent to the `lookat` function? (Assume you move one unit each key stroke - be specific)

4. ｜5 points (bonus)｜ Draw terrain or a landscape scene (1 - 5pts).