You are expected to complete this exam during any two-hour window within the exam period, which runs from Wednesday 8:30 AM to Thursday 8:30 AM. The exam is open-book and open-note:

- You may use all of this course's resources: your class notes, your old homework, and the course Moodle site, the course web site. You may not share any resources with any other person while you are taking the exam.
- You may cite material (definitions, algorithms, etc.) from class and the assigned homework. You do not have to redevelop that material in your solution. On the other hand, you may not cite material that we have not studied, without developing it from the material we've learned.
- You may not consult any other books, papers, Internet sites, etc. You may use a computer for viewing the course Moodle/web site, running our course software, optionally typing up your answers, and e-mailing with me. If you want to use a computer for other purposes, then check with me first.
- You may not discuss the exam in any way — spoken, written, etc. — with anyone but me, until everyone has handed in the exam.

Feel free to ask clarifying questions in person or over e-mail. You should certainly ask for clarification if you believe that a problem is mis-stated. If you cannot receive clarification, then explain your interpretation in your solution.

Your solutions should be thorough, self-explanatory, neat, concise, and polished. You might want to work first on scratch paper and then recopy your solutions. Alternatively, you might want to type your solutions. Always show enough work and justification so that a typical classmate could understand your solutions. If you cannot solve a problem, then write a brief summary of the approaches you've tried. Partial credit is often awarded. Please present your solutions in the order assigned.

Good luck. :)

Here are 12 steps of the triangle rasterization algorithm in alphabetical order.

- choice of fragment color
- choice of fragment depth
- clipping at the near plane
- configuration of uniforms, mesh, textures
- depth test
- homogeneous division
- inverse camera isometry
- modeling isometry
- projection
- rasterization and interpolation
- viewport
- writing of fragment to pixel

Problem A consists of four small questions about the steps above. You do not need to explain your answers in Problem A, unless you feel that there is some ambiguity that merits explanation.

A.A. Rewrite the steps in chronological order (the order of execution in the algorithm).
A.B. Which steps occur in the vertex shader, and which steps occur in the fragment shader?
A.C. Which steps does OpenGL do for us automatically, when we use OpenGL 3.2?
A.D. Which steps must be altered, when we change from perspective-uncorrected interpolation to perspective-corrected interpolation?

Problem B is about scene graphs.

B.A. Draw the scene graph from 380artwork.c. To keep the problem manageable, assume that `NUMTREES` has been set to 3. Draw the scene graph as we want it to be — a rooted graph with arbitrary branching factor — rather than how it's actually stored in memory (the first-child, next-sibling trick).
B.B. Explain precisely how to compute the world coordinates of three corners of the stained glass window. (Depending on where you are in the homework, this problem might be easy.)

Problem C is about lighting. In our lighting calculations, we've been using a directional light, for which $\mathbf{d}_{\text{light}}$ is constant across the whole scene, because the position of the light source is "outside the scene" and "far away" or "at infinity". Suppose now that we want to switch to a light source that is positioned in the scene — for example, a lamp in a room, casting light in all directions.

C. Explain how to change the lighting calculations to implement this new kind of light. Your answer should probably mention how the data sources — attributes, varyings, textures, and other uniforms — change (if they do change).

Problem D is about our textured light algorithm. In that algorithm, we calculate some texture coordinates and sample from the stained glass texture to get a color $\mathbf{c}_{\text{glass}}$.

D. Once you have $\mathbf{c}_{\text{glass}}$, how exactly does it affect the final color of the fragment? (Warning: Some students handled this detail incorrectly in their homework. The answer should make some physical sense, within the limitations of the Phong lighting model. Perhaps you'd like to explain why your answer makes physical sense.)