1. (3 points) State the detailed steps of the 3D viewing pipeline in order (refer to each step in terms of its coordinate reference frame):

(a) Model coordinate frame
(b) World coordinate frame
(c) Viewing coordinate frame
(d) Projection coordinate frame
(e) Normalized coordinate frame
(f) Device coordinate frame

2. (1 point) A Geometric Transformation is an operation applied to the description of an object to change its position, orientation, or size. Those that do not deform the object are considered Rigid-body transformations.

3. (1 point) A Homogeneous coordinate is a \((D+1)\)-dimension representation of a \(D\)-dimensional point. They are used in computer graphics to express Translation as a matrix multiplication.

4. (1 point) Let \(T(t_x, t_y), R(\theta), \) and \(S(s_x, s_y)\), represent two-dimensional translation, rotation, and scale matrices, respectively. What is the composite transformation \(M\) for rotation \(\alpha\) about a pivot point \((p_x, p_y)\)?

\[
M = T(p_x, p_y)R(\alpha)T(-p_x, -p_y)
\]

5. (1 point) Let \(T(t_x, t_y, t_z), R(\vec{v}), R_x(\theta), \) and \(S(s_x, s_y, s_z)\), represent three-dimensional translation, rotation to a vector axis, rotation about the \(x\)-axis, and scale matrices, respectively. What is the composite transformation \(M\) for rotation \(\alpha\) about an axis \(\vec{u}\) with pivot point \((p_x, p_y, p_z)\)?

\[
M = T(p_x, p_y, p_z)R(\vec{u})R_x(\alpha)R^{-1}(\vec{u})T(-p_x, -p_y, -p_z)
\]

6. (1 point) The section of the world selected for display is referred to as the clipping window, while the section of the window to display the scene is called the viewport.

7. (2 points) Clipping is the procedural elimination of primitives that are outside of view. Considering lines, one option is the Cohen-Sutherland algorithm. In two dimensions, each end point of a line is assigned a 4-bit region code. Based on these region codes, to determine if two points are entirely excluded from the scene, a bitwise- and operation is used.

8. (1 point) True or False (Circle one): The Weiler-Atherton method of eliminating polygons algorithmically traces the boundary of a polygon to build up final vertex lists included in a scene.
9. (2 points) Considering three-dimensional viewing, describe the three step process for determining camera parameters:

(a) Choose a eye position
(b) Choose a look-at point
(c) Choose the up vector

Let $T$ be the translation and $R$ be the rotation matrices from your process. What is the composite transformation $M$ to the $\vec{u}\vec{v}\vec{n}$ reference frame? 

$$M = RT$$

10. (2 points) Considering three-dimensional viewing. In perspective projection, parallel lines appear to converge in the distance. The view volume in this projection is a frustrum. In parallel projection, relative lengths and proportions remain accurate no matter the distance an object is from a camera. A subset of this, a(n) oblique parallel projection, projects objects along a direction relative to the viewplane.

11. (1 point) Bonus. There is a memory and operation efficient representation of rotations. What are they called, what are they, and how do you express a point $\vec{p}$ and an angle-axis rotation $(\theta, \vec{u})$ with them?

Quaternions. A quaternion $q = (s, \vec{v})$ is a four dimensional complex number with one real (scalar) component $s$ and a vector (three imaginary numbers) component $\vec{v}$. A point $\vec{p}$ would be represented as $(0, \vec{p})$ and an angle-axis rotation $(\theta, \vec{u})$ would be represented as $(\cos(\frac{\theta}{2}), \vec{u}\sin(\frac{\theta}{2}))$. 