1. (15 pts)
   (a) (6 pts) Write the $4 \times 4$ translation matrix $T$ for a translation with displacements $\Delta x = 5$, $\Delta y = 2$, and $\Delta z = -1$.
   (b) (6 pts) Write the $4 \times 4$ rotation matrix $R$ for a rotation with angle $45^\circ$ about the positive $x$-axis.
   (c) (3 pts) Which is the correct matrix for the combined translation in part (a) followed by the rotation in part (b): $RT$ or $TR$?

2. (18 pts) Let the eye point be $E = (3, 4, 0)$, the look point be $L = (0, 0, 0)$, and the up vector be $\text{up} = (1, 1, 0)$.
   (a) (10 pts) Find the three basis vectors $u$, $v$, and $n$ of the eye coordinate system.
   (b) (8 pts) Find the $4 \times 4$ view matrix that transforms world coordinates into these eye coordinates.

3. (6 pts) In general, what are the coordinates of the eye point in the eye coordinate system? Where is the look point in the eye coordinate system?

4. (18 pts) The function call $\text{glFrustum}(l, r, b, t, n, f)$ creates the projection matrix
   \[
   P = \begin{pmatrix}
   \frac{2n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\
   0 & \frac{2n}{t-b} & \frac{t+b}{t-b} & 0 \\
   0 & 0 & -\frac{f+n}{f-n} & \frac{2fn}{f-n} \\
   0 & 0 & -1 & 0
   \end{pmatrix}.
   \]
   (a) (6 pts) Find the projection matrix for the function call $\text{glFrustum}(-2.0, 2.0, -1.0, 1.0, 0.1, 10.0)$.
   (b) (6 pts) Use the projection matrix in part (a) to transform the point $A = (2, 1, -1, 1)$ (in eye coordinates) to clip coordinates.
   (c) (6 pts) Use your answer in part (b) to decide whether the point $A$ should be clipped. Explain how you made your decision.

5. (12 pts) Vertices are transformed from world coordinates to eye coordinates, at which point the lighting effects are calculated. Then the vertices are transformed to clip coordinates, at which point primitives are clipped.
   (a) (6 pts) If primitives were clipped in eye coordinates, then there would be fewer vertices left to transform into clip coordinates. Why is this not done?
   (b) (6 pts) If lighting were postponed until after the primitives were clipped, there would be fewer vertices left for which to calculate the lighting effects. Why is this not done?
6. (6 pts) When designing a black-and-white checkerboard texture, the programmer may create a $4 \times 4$ texture, shown below on the left, or a $2 \times 2$ texture, shown below on the right. Obviously, the $2 \times 2$ texture saves memory. What is a good reason for using the $4 \times 4$ texture?

7. (10 pts) Apply the Bresenham algorithm to the line from $(0, 0)$ to $(7, 3)$. Show explicitly the calculations involved for each value of $x$ from 0 to 6. Then draw the rasterized line in the grid below.
8. (9 pts) In the drawing below,
   
   (a) (3 pts) Show clearly the bounding box of the polygon.
   
   (b) (6 pts) Shade the pixels that belong to the polygon, according to the rules that we stated in class.

9. (6 pts) Explain how the framebuffer is used to solve the problem of hidden-surface removal.