Name:

Instructions: Read questions carefully before answering. Do not hesitate to ask for clarifications. Show all work. Partial credit is given, so do not leave anything blank! Ask for extra paper if you need it! Good luck!

Bonus Question (1 point) What is the name of WPI’s provost?

Question 1: (16 points) Short Questions

Briefly answer the following questions

a. What is a scene graph?

b. What is a vertex attribute?

c. Why is it preferable to pre-multiply matrices together and get a final transform matrix before applying the resulting matrix to each vertex of a mesh?

d. Give a real world application that uses a picking input
Question 2: (12 points) OpenGL/GLUT

a. What argument of glDrawArrays would you use to draw a closed loop of polylines?

b. If your program has set up multiple VBOs, what command would you use to make one of them active?

c. In the fragment shader, variables declared as "in" are received from where?

Question 3: (12 points) View Transformation

You are looking at a mesh of a cow that is positioned at origin from the position (x, y, z) with up vector (ux, uy, uz) and have computed your viewing transformation matrix $M$ using lookAt. You now want to look at the other sides of the cow mesh by simply moving to a new viewing location (e.g. $-x$, $-y$, $-z$) but with the same up vector (ux, uy, uz). Can you reuse some elements of the previously calculated viewing matrix $M$? Or would you have to recalculate the matrix $M$ from scratch? If you can reuse $M$, write out the viewing matrix $M$ and circle which elements would CHANGE when you change the viewing position as in the above scenario. If you cannot reuse any elements of the matrix $M$, say why.
Question 4: (12 points) Window-to-Viewport Mapping

John is trying to draw a picture of his mum that has WxH = 200 x 150 pixels into a viewport that is WxH = 80 x 10. Specify the width x height of the largest picture he can draw while maintaining aspect ratio.

Question 5: (18 points) Transformations

a. (4 points) \( S \) is the scale matrix with scaling factors \( S_x = 6, S_y = 12, S_z = 8 \). Write out its inverse matrix.
b. (14 points) Using Euler's rule, write out in matrix form, the sequence of X, Y and Z rolls that can be used to achieve a rotation of 30 degrees about an arbitrary axis that has azimuth = 35 degrees and latitude = 46 degrees. You don't have to multiply these matrices together. Just write out ALL THE MATRICES IN FULL.

Question 6: (12 points) Vectors in Graphics

Give a formula for finding a reflection $r$ the reflection of a vector $a$ about a surface with normal $n$. Using this formula, what is the value of the reflection vector $r$ if $a = (4,-2)$ and $n = (0, 3)$.
Question 7: Coordinate Systems (8 points)

We have discussed several different coordinate spaces, including:

(i) Screen coordinate space
(ii) World coordinate space
(iii) Camera coordinate space

Finish each of the statements below with either (i), (ii), or (iii), and give a reason for your answer (4 points each).

a. Object transformations are most easily specified in...

b. A viewport is specified in...
Question 8 (10 points): Fractals

What is the resulting string from the following L-System grammar, iterated twice?

```
rot: 60.0 60.0 60.0
start: F++F++F++
F: F−F++F−F
```

String after 1st iteration (4 points):

String after 2nd iteration (6 points):