STUDENT NAME:
ID NUMBER:
CLASS YEAR:

ACADEMIC HONOR CODE

Students and faculty at Smith are part of an academic community defined by its commitment to scholarship, which depends on scrupulous and attentive acknowledgement of all sources of information and honest and respectful use of college resources.

Smith College expects all students to be honest and committed to the principles of academic and intellectual integrity in their preparation and submission of course work and examinations. All submitted work of any kind must be the original work of the student who must cite all the sources used in its preparation.

Student Signature: ______________________________

EXAM INSTRUCTIONS

ALL ANSWERS SHOULD BE SCANNED AND SUBMITTED ON MOODLE.

PLEASE INCLUDE THE SIGNED AND SCANNED HONOR CODE STATEMENT FROM THE FRONT PAGE OF THIS EXAM.

YOU MAY USE COURSE NOTES AND INTERNET REFERENCES.
YOU MAY USE A CALCULATOR OR COMPUTER.
YOU MAY NOT DISCUSS ANY PART OF THIS EXAM WITH ANY PERSON OTHER THAN THE INSTRUCTOR, ELECTRONICALLY OR OTHERWISE.

THIS EXAM CONSISTS OF SIX (6) PAGES WITH EIGHT (8) QUESTIONS
Line Drawing (16 pts)

A line needs to be drawn from (0.7,3.1) to (5.5,1.5) on each of the very small canvases below. (Each square is one pixel.) Show the pixels that would be filled in for each case.

a.) Simple line algorithm using pixel-center origin.
b.) Incremental midpoint algorithm using corner origin.
c.) Antialiased line using corner origin. (In the diagram, indicate all pixels that would be shaded even partially. You do not need to show the amount of shading.)
d.) For the line in part (b), what is the value of the discriminator \( F(x,y) \) at the midpoint \( y = 4.5 \)?

Subsurface Scattering & Raycasting (20 pts)

A translucent sphere is to be rendered with long-range subsurface scattering. The sphere has radius 10 and its center is at (0,0,-14). There is a light source located behind the sphere at (0,30,-30). Although subsurface scattering is usually simulated using standard rendering with a z-buffer, for this problem you should use raycasting to answer the questions below.

a.) Give an equation for the ray that goes from the light source to the camera focal point (located at the origin).
b.) Find the coordinates of the point(s) where the ray you computed in part (a) intersects the surface of the sphere.
c.) If the intensity of subsurface scattered light is given by \( I_{SS} = e^{-d/10} \), where \( d \) is the thickness of the material, what is the intensity that will be computed for the visible point in part (b)?
d.) Suppose that the display is 220 pixels wide and 220 pixels tall, with the viewport at \( z = -1 \) and extending to \( \pm 1.1 \) on both \( x \) and \( y \) axes. The focal point is at the origin and the camera points in the –z direction. Give the standard form of the ray equation that goes through pixel (130,0).
e.) Find the 3D coordinates of the point where the ray from (0,0,0) through (1,2,-2) intersects the triangle ABC, where \( A=(0,0,-4) \), \( B = (4,0,-2) \), and \( C = (0,4,-4) \).
Texture Mapping (12 pts)

Letters are shown on the faces of a cube by mapping a texture onto it using the UV coordinates generated with the code shown below. Each face of the cube is made of two triangles, as shown in the image at right, with vertices always listed in the order ABC, then BDC. The six faces of the cube are labeled with ?, 4, R, F, B and G as indicated in the code comments. Infer the appearance of the texture source image, and draw what it must look like. Pay attention to both position and orientation. (You may assume that any unused portions of the texture source image are blank.)

```javascript
geometry.faceVertexUvs[0] = [
    [new THREE.Vector2(0.00,1.00),new THREE.Vector2(0.00,0.75),new THREE.Vector2(0.25,1.00)], // upper left ?
    [new THREE.Vector2(0.00,0.75),new THREE.Vector2(0.25,0.75),new THREE.Vector2(0.25,1.00)], // lower right ?
    [new THREE.Vector2(0.50,1.00),new THREE.Vector2(0.50,0.75),new THREE.Vector2(0.75,1.00)], // upper left 4
    [new THREE.Vector2(0.50,0.75),new THREE.Vector2(0.75,0.75),new THREE.Vector2(0.75,1.00)], // lower right 4
    [new THREE.Vector2(0.00,0.25),new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.00,0.50)], // upper left R
    [new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.25,0.50),new THREE.Vector2(0.00,0.50)], // lower right R
    [new THREE.Vector2(0.75,0.25),new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.75,0.00)], // upper left F
    [new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.25,0.00),new THREE.Vector2(0.75,0.00)], // lower right F
    [new THREE.Vector2(0.75,0.50),new THREE.Vector2(0.75,0.00),new THREE.Vector2(1.00,0.50)], // upper left B
    [new THREE.Vector2(0.75,0.00),new THREE.Vector2(1.00,0.00),new THREE.Vector2(1.00,0.50)], // lower right B
    [new THREE.Vector2(0.25,0.75),new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.75,0.75)], // upper left G
    [new THREE.Vector2(0.25,0.25),new THREE.Vector2(0.75,0.25),new THREE.Vector2(0.75,0.75)]  // lower right G
];
```
Shading (10 pts)

Clearly identify all the surface points in the scene below whose shading intensity will be a local maximum (i.e., brighter than the neighboring surface points on either side). Assume perspective projection and a Phong reflectance model with large alpha. Surface reflectance is uniform everywhere. Include points that may not be visible from the camera’s position, as long as they are lit.

Splines (8 pts)

Please answer the questions below concerning splines

a.) A smooth closed loop curve will be represented using a cubic Bézier spline with five individual segments. How many unique control points will be required to specify the entire curve?
b.) A smooth closed loop curve will be represented using a cubic Bézier spline with five individual segments. How many unique control points must the curve pass through?
c.) A smooth closed loop curve will be represented using a cubic polynomial spline with five individual segments. How many unique control points will be required to specify the entire curve?
d.) A smooth closed loop curve will be represented using a cubic polynomial spline with five individual segments. How many unique control points must the curve pass through?
Matrices & Transformations (16 pts)

Using the transformation matrices provided below, compose a transformation that will have the effect described. If the effect is not possible using the matrices given, say “not possible.”

F: Convert the model coordinates of a flowerpot into world coordinates with root position $p_f$
G: Convert the model coordinates of a garden gnome into world coordinates with root position $p_g$
H: Convert world coordinates to camera coordinates
O: Orthographic projection
P: Perspective projection with a focal length of 4
Q: Convert projected coordinates to screen coordinates
R: Perform 3D rotation by 180 degrees around the z axis
S: In 3D, scale the z coordinate by a factor of 2
T: Translate in 3D coordinates from $p_f$ to $p_g$

a.) Place the garden gnome in the scene at position $p_f$
b.) Place the flowerpot in the scene upside-down at position $p_f$
c.) Convert world coordinates to screen coordinates under perspective projection
d.) Convert screen coordinates to world coordinates under orthographic projection
e.) Convert flowerpot model coordinates to camera coordinates (assuming the flowerpot is at $p_f$)
f.) Convert camera coordinates to flowerpot model coordinates (assuming the flowerpot is at $p_f$)
g.) Convert camera coordinates to projected coordinates under perspective projection with a focal length of 2.
h.) Convert camera coordinates to projected coordinates under perspective projection with a focal length of 6.

Three.js (8 pts)

Answer the questions below about Three.js. You may use the online Three.js documentation to research your answers.

a.) Class used to represent a homogeneous 3D transformation
b.) Class used to represent a UV coordinate
c.) Class used to perform raycasting
d.) Class used to create a virtual object for purposes of hierarchical modeling
e.) Class used for representing the shape of 3D text in a scene
f.) Class used for adding a particle cloud to a scene
g.) Expression to create a camera object for a canvas 120 pixels wide by 80 pixels tall, using perspective projection with a 90 degree field of view, clipping objects nearer than 2 units and farther than 80
h.) Expression to create a pure green light source of default intensity, extending 15 units in every direction, without decay
The diagram below shows a cross-section of objects in world coordinate space. The camera is placed at the origin and points in the negative z direction. Please answer the questions that follow.

a.) Under the painter’s algorithm, in what order would the objects be rendered?
b.) Using z-buffering and orthographic projection, and assuming that the objects are rendered in alphabetical order, which objects would never be drawn in the scene at all?
c.) Using z-buffering and orthographic projection, and assuming that the objects are rendered in alphabetical order, which objects would be partially or completely overpainted?
d.) Using z-buffering and orthographic projection, and assuming that the objects are rendered in alphabetical order, what would be the contents of the z-buffer after objects A-G have rendered?
e.) Assuming perspective projection, with field of view 90 degrees, near clipping plane at z=-0.5 and far clipping plane at z=-13.5, which objects would be visible in the final rendering?