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CS174A – Introduction to Computer Graphics
FINAL EXAM: SPRING 2021 (June 7, 2020)

1. **Plane equation and back-face determination**
    - **a.** (10 points) Given the following 3 points (in CCW order), find its plane equation by first finding its normal: (1,0,0), (0,1,0), (0,0,1)
    - **b.** (5 points) Write a 4x4 HM for translation by (1,1,1)
    - **c.** (10 points) Apply the translation matrix to the first vertex and the normal from part (a)
    - **d.** (5 points) If the eye is located at (0,0,0), determine if the above polygon is a front-face or a back-face wrt the eye

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2. Z-Buffer Algorithm & Sprites

- **a.** (5 points) For a polygon's plane equation given by –x-2y+3z-4=0 (in screen space), find the depth of the plane at pixel (4,4)
- **b.** (5 points) Using incremental calculations, find the depth at pixel (4,5)
- **c.** (5 points) If a particle is at depth 5 units at pixel (4,4), determine if the particle's color or poly's color will be displayed at this pixel
- **d.** (10 points) Explain in brief how z-buffer algorithm handles penetrating polygons and cyclic polygons that Painter's algorithm has difficulty with

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3. Illumination

a. (10 points) What is meant by radiosity in computer graphics? Which component in the illumination equation would it replace and why?

b. (10 points) Given the following, calculate the specular component of illumination using halfway-vector; ignore attenuation due to distances between light/eye and point
Point location: 0,0,0; Light location: 1,1,1; Eye location: -1,-1,1; Normal: 0,0,1
Specular exponent: 2; Coefficient of specular reflection: 0.1; Intensity of point light: 0.2

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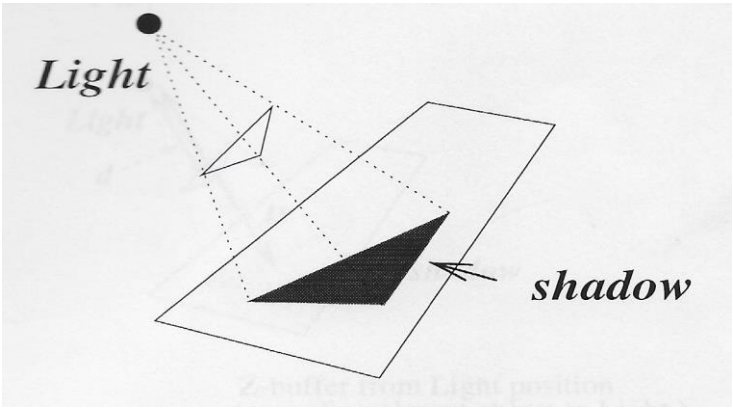
4. Shadows

a. (15 points) For the following scenario, find out the coordinates of the vertices of the shadow on the xz-plane. Light is located on the y-axis at (0,10,0). Coordinates of the triangle are (0,4,0), (4,4,0), and (0,4,4); figure below does not exactly correspond to these coordinates, use it for illustration purposes only

Hint: xz-plane is given by plane equation: y = 0; find parametric rays from the light location through the 3-vertices of the triangle and intersect them with xz-plane.



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5. Shading

a. (10 points) For shadows to work accurately using 2-pass z-buffer algorithm, which shading model would you use, and why?

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6. Mappings

a. (8 points) Explain how aliasing may occur while mapping the following texture on an object or polygon

b. (7 points) Explain how you would simulate the reflection of the surrounding on the bean in Chicago (like shown below) without doing ray-tracing.

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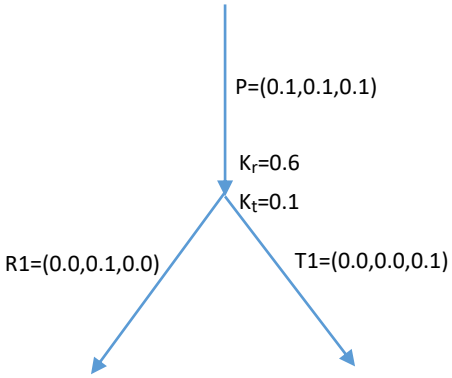
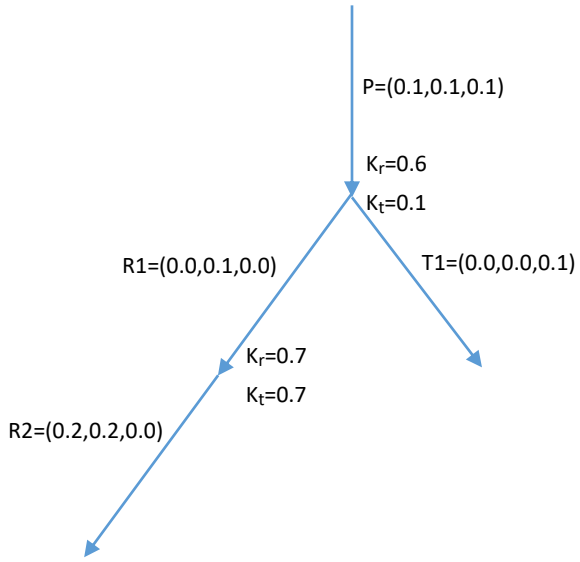
7. Ray Tree

For the following 2 ray trees, find the color displayed for the corresponding pixel. Illuminated RGB colors returned by primary (P), reflection (R1/R2), and transmission (T1) rays are indicated on the arrows; reflection and transmission coefficients (K_t and K_r) are indicated at each intersection node. Note that part (b) is an extension of part (a).

(a) 9 points



(b) 6 points



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8. Ray Tracing

Let's implement a ray tracer for a triangle

Ray origin: (0,0,0)

Ray passes through: (1,1,1)

Triangle vertices: (0,4,0), (8,0,0), (0,0,8)

- **a.** (3 points) Find parametric equation of ray
- **b.** (7 points) Find equation of the plane in which triangle lies
- **c.** (10 points) Using method discussed in class, intersect ray with the plane of the triangle
- **d.** (5 points) Explain how you would determine that the intersection point actually lies inside the triangle; no calculations needed for this part of the question, only explain the steps as specifically as you can

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9. Volume Rendering

a. (5 points) Explain in brief the process of Marching Cubes used for volume rendering
(5 points) List one advantage and one disadvantage of this volume rendering method

b. (10 points) Let's say the "footprint" of a splat looks like a square covering 4 pixels, and let's say the RGBA of a voxel gets divided equally amongst the 4 pixels in a splat. For 2 adjacent voxels that splat on the screen as shown below, find the final RGBA values used to display these 6 pixels. Note that the splats of the 2 voxels overlap at the middle 2 pixels
Voxel 1 (front): (0.4,0.4,0.0,0.8)
Voxel 2 (back): (0.0,0.2,0.2,0.4)