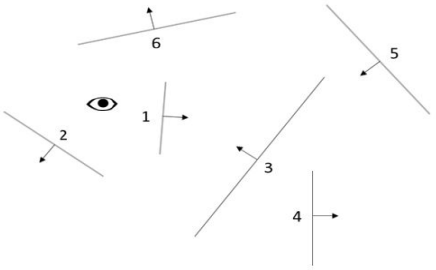
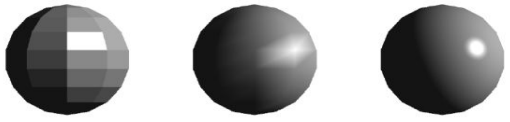
Interactive Computer Graphics Mid-term Exam, November 22, 2018

1. BSP Tree (10%)
   - Construct the Binary Space Partitioning (BSP) tree of the following figure. Please use the node "3" as the root, and choose smaller numbers as the sub-tree root node. (5%)
   - From the BSP tree of previous question, derive the display sequence in terms of the given viewing position in this figure. (5%)



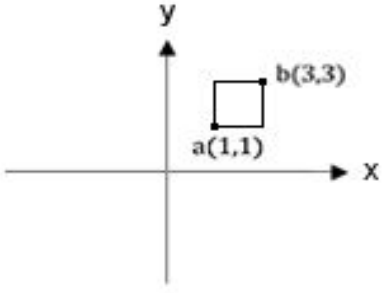
2. Shading (6%)
   - In homework 1, you implement three kinds of shading.
     Consider each figure below, determine which kind of shading it uses and explain your reason respectively. (6%)



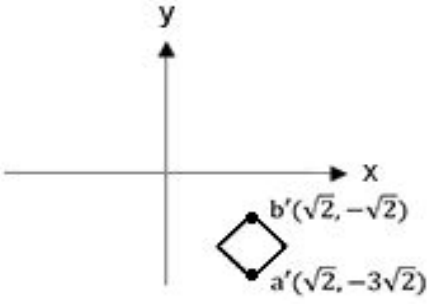
(A) (B) (C)

3. GPU rendering pipeline (10%)
   - Describe the GPU rendering pipeline. (4%)
   - What is the meaning of model matrix, view matrix and projection matrix ? Please describe them respectively. (6%)

4. Transformation matrix (12%)
   For the following questions, consider as 2d plane. You need to **write down all 3x3 matrices** respectively and the matrix multiplication order.
   - For the figures below, find transform matrices to convert the square in (A) into the square in (B) (6%)

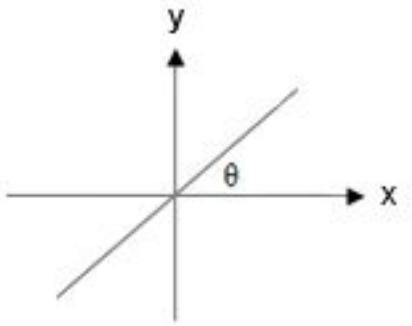


(A)



(B)

- The simplest way to simulate a mirror is to copy objects which is symmetric to the mirror. Now given a mirror line with angle θ, please find transform matrices to do this. (6%) (Hint : use scale matrix with minus value)



5. Ray intersection (8%)

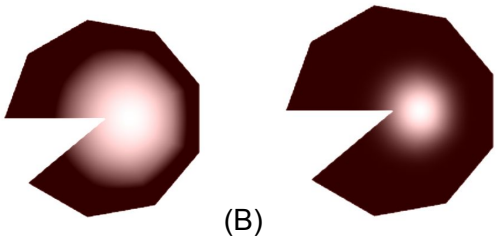
- In ray tracing, we need to judge if the ray intersects with a shape or not. Given a ray in 3d $(x_t, y_t, z_t) = (v_x, v_y, v_z) \times t + (o_x, o_y, o_z)$, $t \geq 0$, and a square formed by 4 points (-r, -r, 0), (-r, r, 0), (r, r, 0), (r, -r, 0), where $(v_x, v_y, v_z) = (-1, -1, -1)$ and $(o_x, o_y, o_z) = (4, 5, 6)$, r = 2.5. Check if the ray intersects with the square, and calculate the intersection point if any one of them exists.

6. (5%) What is your term project for this semester? What are the technical difficulties involved in the project? (You can refer to the project listing).

7. Phong illumination model (4%)

$$I = k_a I_a + \sum_{lights} (k_d I_{m,s} \cos\theta + k_s I_{m,d} \cos^{\alpha}\theta)$$

- In Phong illumination model, the specular value α is also a parameter of material. Compare images below, which specular value is larger? (4%)



(A) (B)

8. Rendering equation (6%)

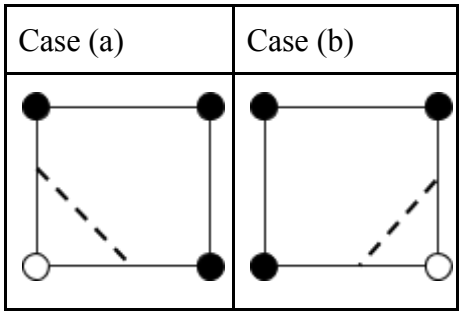
$$L_o(\mathbf{x}, \omega_o, \lambda, t) = L_e(\mathbf{x}, \omega_o, \lambda, t) + \int_{\Omega} f_r(\mathbf{x}, \omega_i, \omega_o, \lambda, t)\, L_i(\mathbf{x}, \omega_i, \lambda, t)\, (\omega_i \cdot \mathbf{n})\, \mathrm{d}\omega_i$$

- Can Phong illumination model solve the rendering equation ? Why or why not ? (6%)

9. Volume Rendering / Marching Cubes (12%)

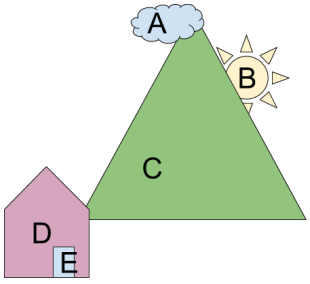
- Please give two examples for Volume Rendering applications. (4%)
- Volume Rendering use marching cubes to determine the contour of the volume. Now we consider the 2d condition, i.e. square marching. The square marching consists of two steps. First, apply the threshold of contour, and label the point with black if the value of the point is lower than threshold, otherwise label with white.

  Second, determine the contour by the case of 4 points' color. For example, in the case (a) and case (b), the contour is the dash line shown in the picture.



  - How many cases should square marching consider? **Draw all of them**. Each case should include 4 points and contour. Note that case(a) and case(b) are different. If there are any ambiguity of possible contour exists, just draw one of them. (8%)

10. Painter's algorithm (4%)



E is a door of the house D.

- In image above, what is the drawing order if we use painter's algorithm? If multiple possible answers exist, answer one of them. (4%)

11. (8%) It is said that Microsoft game machines X-Box (1, and 360) are costing more than their sale prices, and then use the game software revenue to compensate for the loss in hardware.

(a) If this is true, what advantages for Microsoft in developing the hardware platform can be predicted from this business model? (4%)

(b) In the above case, is it easy for companies from Korea or Taiwan to develop their own game machines or clones of these machines? Why and why not? (4%)

12. (15%) Modified Distribution Ray tracing

(a) What's the weakness of ray-tracing as compared to the Rendering equation? (short answer) (5%)

(b) In the photo below, there are very bright spots under the glass sphere, called caustics. One way to improve the previous ray-tracing is to combine the rays (light packets) shooting from the lights, and store the (location, direction) information at the light-surface intersection points, called photon maps. (10%)

For caustics, we only store the photon map when rays hit the highly specular surface or pass through a transparent object and finally reach a diffuse surface.

After the photon maps are created, we can use ray-tracing to shoot rays from the eye until it hits the surfaces with the photon maps. Why is this method successful in solving the Rendering Equation? Please give your own algorithm describing the previous solution.