Fall 2018 FINAL EXAM -- SOLUTION

Course Number and Section: CSC 240

Course Title: Introduction to Computer Graphics

Instructor: Nicholas R. Howe

STUDENT NAME: **EXAM DATE:**

ID NUMBER:

CLASS YEAR: **EXAM OUT:**

EXAM FORMAT: **EXAM DUE:**

Number of Blue Books per student: 1 **EXAM IN:**

All blue books, used or unused, must be returned with the exam.

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 WRITTEN IN YOUR EXAM BOOKLET.

YOU MAY USE ONE 8.5"x11" DOUBLE-SIDED SHEET OF NOTES ON THIS EXAM.

YOU MAY NOT USE THE TEXTBOOK, A COMPUTER, OR ANY OTHER INFORMATION SOURCE BESIDES YOUR TWO PAGES OF NOTES.

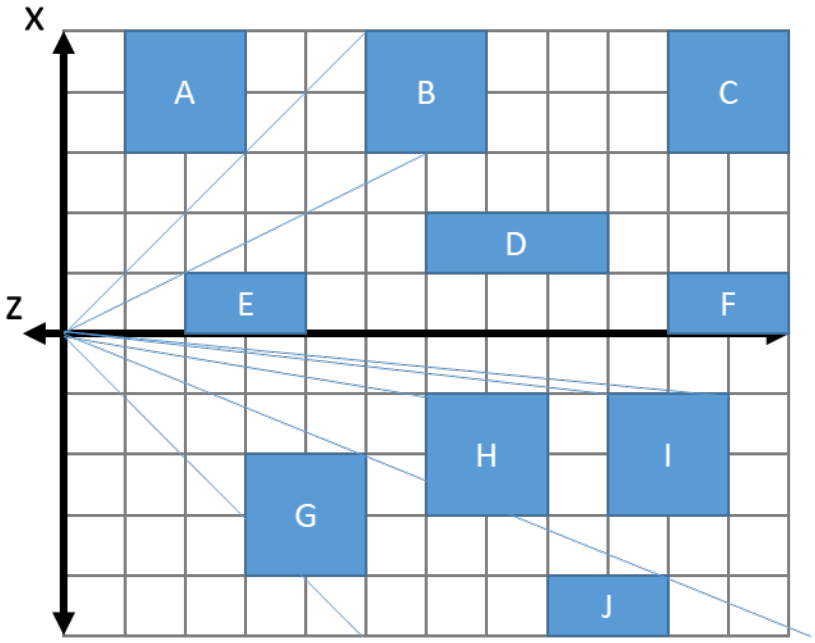
THIS EXAM CONSISTS OF FOUR (4) PAGES WITH SIX (6) QUESTIONS

Projections

The diagram below shows a cross-section of objects in world coordinate space. Identify which objects would be visible under each of the following camera conditions. In both cases the camera is placed at the origin and points in the negative z direction.

a.) Perspective camera, FOV 90°, near=1, far=11
Visible: B, E, I, H, G. (Sight lines shown)

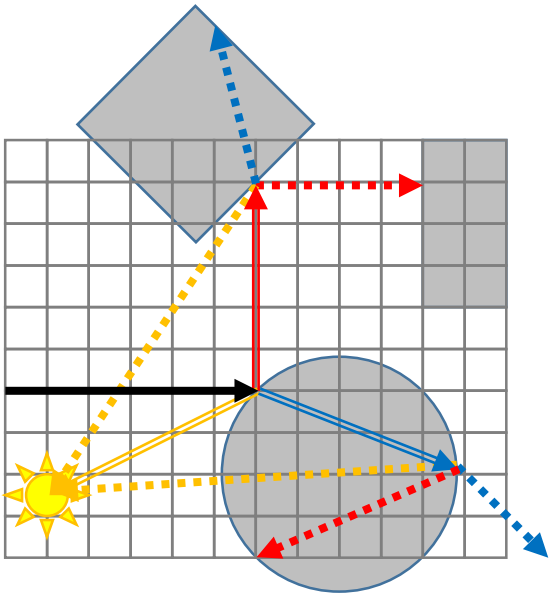
b.) Orthographic camera, view plane -5 to +5.
Visible: A, D, E, H, G, J



Hierarchical Ray Tracing

A ray of light is cast into an array of objects as shown at right. The shaded areas are objects with index of refraction N = 1.4, while the unshaded areas all have N =1. The sun represents a light source. For the primary ray shown, draw the secondary and tertiary rays that would be created. Label each ray according to its type (e.g., the physical process that it is simulating).

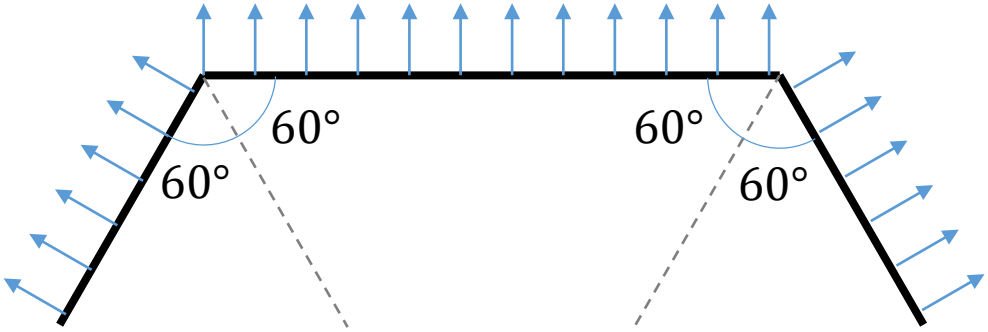
Answer shown at right. Reflection rays are red; transmission rays are blue; shadow rays are amber.



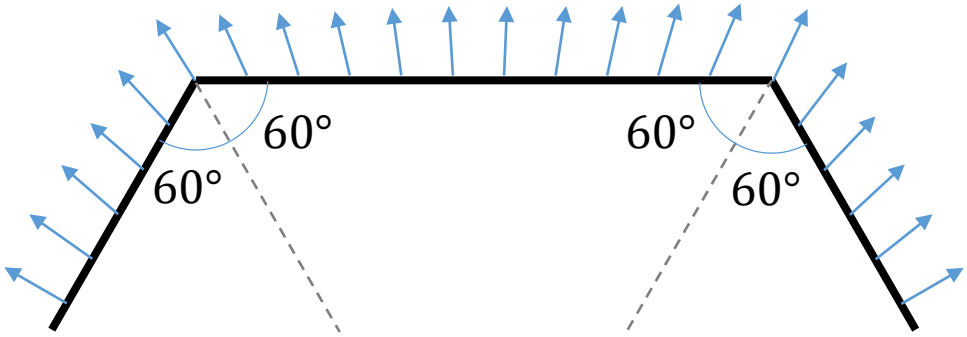
Surface Normals

The upper side of the diagrams below represents the outside of a polyhedral shape. Draw the surface normals that would be associated with each of the following conditions.

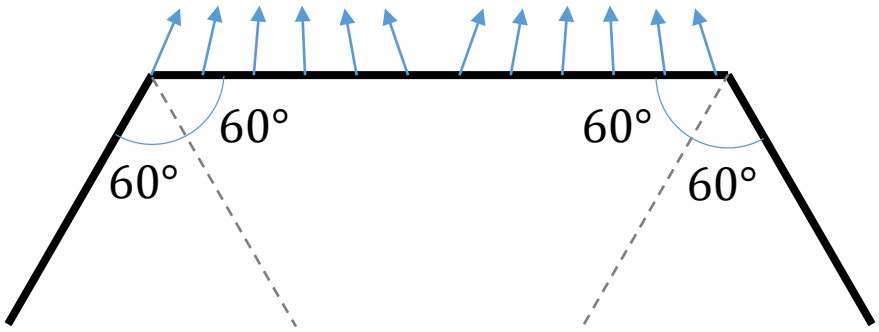
a.) Faceted shading

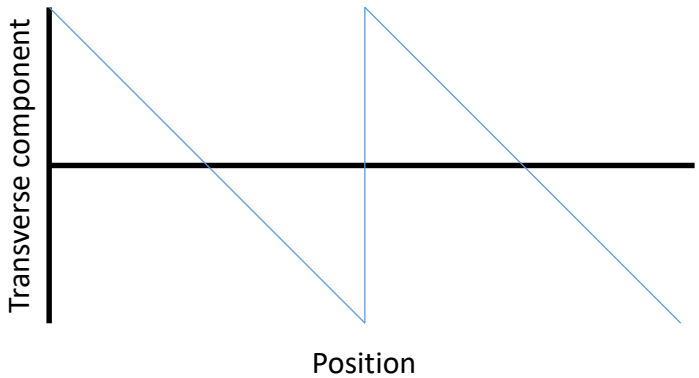


b.) Smooth shading



c.) Use the normal map shown on the top face:





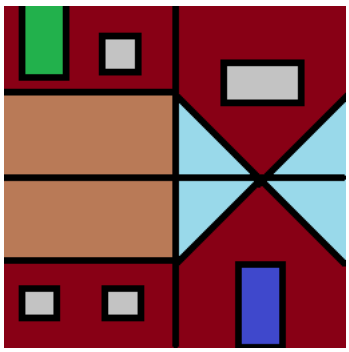
Texture Mapping

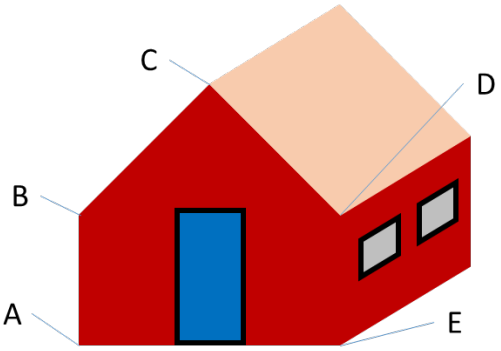
Consider the texture map below left, which is intended for use with the model of a small gabled house shown in isometric 3D view below right.

a.) Give the UV coordinates of the five corners of the front of the house (A-E).
A: (1/2,0); B: (1/2,1/4); C: (3/4,1/2); D: (1,1/4); E: (1,0)

b.) Propose a set of triangles that will render the front of the house. List their corner points (e.g., XYZ) in the correct order to generate an outward-facing normal.
CBA, CAE, CED; or DCB, DBA, DAE; or BDC, BED, BAE; or ACB, ADC, AED; or EDC, ECB, EBA.

c.) The house model has four sides, two roofs, and a bottom. What is the minimum number of triangles it will take to render? *16*





Ray Casting

a.) Consider the triangle ABC, where A = (18,18,0), B = (18,0,18), and C = (0,18,18). Find the point where the ray from (0,0,0) to (1,2,3) intersects the triangle.

Plane = (18,18,0)+u(0,-18,18)+v(-18,0,18)

t = 18-18v; 2t = 18-18u ➔ t = 9-9u; 3t = 18u+18v ➔ t = 6u+6v

18-18v = 9-9u = 6u+6v; 9+9u = 18v; u = 2v-1. 9-6v = 15u; 3 = 5u+2v; 3 = 10v-5+2v; v = 2/3; u = 1/3; t = 6

Point = (18,18,0)+(0,-6,6)+(-12,0,12) = (6,12,18)

b.) A camera has a 90° field of view and an aspect ratio of 1.25. The canvas is 450 by 360 pixels. Determine the ray equation (in standard form) for the ray that goes through pixel (180,120), assuming that the viewport is at z = -12.

The viewport is at z = -12. Then $y_{max} = 12 \tan 90° = 12.$
$x_{max} = 1.25 \cdot 12 = 15.$ *x = (180/450)*(2*15)-15 = -3. y = (120/360)*(2*12)-12 = -4.*
Ray is from (0,0,0) to (-3,-4,-12). Standard form is R(t) = (0,0,0)+t(-3/13,-4/13,-12/13)
In decimal format, R(t) = (0,0,0)+t(-0.23, -0.31, -0.92)

Lighting Models

Describe how the Phong model uses the surface normal vector to compute the color of a surface point under a mixture of directional and ambient light. Be sure to mention any surface properties that come into play.

Several different types of reflection are simulated under the Phong model, and each makes a contribution to the final color. In general the amount of light available for a particular reflection mode will be combined with the reflectivity of the surface for that mode. The angle between the light, the surface normal, and the viewer's position matters for some reflection modes but not others. Specifically, the point's color will be the sum of its ambient reflectivity times the ambient light intensity, plus the diffuse reflectivity times the dot product of the normal with the light direction (if positive), plus an amount that depends on the specular reflectivity times the directional light intensity times the dot product of the view angle with the reflection normal, raised to a power representing the material's shininess. The equation from the text is

$$I_r = la_r * ma_r + f * (ld_r * md_r * (L \cdot N) + ls_r * ms_r * \max(0, V \cdot R)^{mh})$$

Object Hierarchies

Consider the five points P_1 through P_5. They are arranged in a hierarchy such that P_1 is the parent of P_2, P_2 of P_3, etc. Assume that each point is located at the origin in its own reference frame, before transformations.

a.) Where will each of the five points end up in world coordinate space after the following transformations have been applied?

P_1.translate(5,0,0); P_2.translate(0,2,0); P_3.translate(0,0,-1); P_4.translate(-5,-2,1); P_5.translate(1,1,1);

(5,0,0), (5,2,0), (5,2,-1), (0,0,0), (1,1,1)

b.) Now assume that the following transformation is applied after those above. Where will all the points end up now?

P_4.scale(1,1,2);

(5,0,0), (5,2,0), (5,2,-1), (0,0,1), (1,1,3)

c.) One more transformation is applied after all those listed above. Give the final world coordinates of all the points.

P_2.rotateX(π/2)

(5,0,0), (5,0,2), (5,1,2), (0,-1,0), (1,-3,1)