University of California San Diego
CSE167: Introduction to Computer Graphics
Midterm Examination
Thursday October 30, 2008

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Name:_____

Please write your name or initials at the top of every page.

Please include all steps of your derivations in your answers to show your understanding of the problem. Try not to write more than the recommended amount of text. If your answer is a mix of correct and substantially wrong arguments we will consider deducting points for incorrect statements. You may not use calculators, notes, textbooks or other materials during this exam. There are twelve questions for a total score of 100 points.

Good luck!

1. Given the vectors **a** = (3, 0, 4) and **b** = (2, 4, –4).

   a) What is the magnitude of each vector? (4 points)

   b) Compute the dot-product of the two. (3 points)

   c) Is the angle between **a** and **b** smaller or greater than 90 degrees? (1 point)

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2. Given two vectors **x** = (3, 2, 5) and **y** = (2, 4, -4). Vector **z** is the cross product **x** × **y** (you do not need to calculate **z**). We decide to use these vectors as the basis vectors of a coordinate system, in the order **x**, **y**, **z**.

a) Is this coordinate system a left-handed or right-handed coordinate system? Why? (2 points)

b) Is it a Euclidian coordinate system? Why? (2 points)

c) Would it be a Euclidian coordinate system if **x** = (1, 2, 2) instead (**y** and **z** as above), and we normalized **x**, **y**, and **z**? (2 points)

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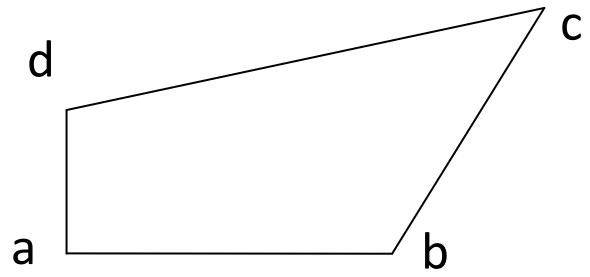
3. You are looking down at a flat quadrilateral, defined by four points that all lie in a plane:



Write an expression for the normalized normal vector **n** to this quadrilateral. The normal should be pointing towards you (out of the paper).
Notation: **a•b** for dot product of vectors **a** and **b**, **a**×**b** for cross product of **a** and **b**, and |**a**| for magnitude of **a**. (8 points)

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4. a) Calculate a 4x4 rotation matrix which rotates points about the vector **a** = [0,1,0] by 90º. (6 points)
b) What rotation matrix rotates points about the same vector **a** but in the other direction? (2 points)

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5. Consider a homogeneous affine transformation matrix **M**, constructed from columns **a**, **b**, **c** and **d** as follows:

$$\begin{bmatrix} a_x & b_x & c_x & d_x \\ a_y & b_y & c_y & d_y \\ a_z & b_z & c_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

a) Write the result of transforming $\begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$ by **M**, in terms of **a**, **b**, **c** and **d**. (4 points)

b) Suppose this matrix represents the local-to-world transform of an object that is not changing position, but is spinning about its local z-axis. Which column or columns (**a**, **b**, **c** or **d**) of the matrix will *not* change as the object spins? (4 points)

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6. Given a point p with *camera space* coordinates p = (2, 1, 1). In addition, camera space has its origin at $(2,\frac{1}{\sqrt{2}},-\frac{1}{\sqrt{2}})$ in *world space*, and the basis vectors of camera space have *world coordinates* $(0,1,0)$, $\left(\frac{1}{\sqrt{2}},0,\frac{1}{\sqrt{2}}\right)$, $\left(\frac{1}{\sqrt{2}},0,-\frac{1}{\sqrt{2}}\right)$. What are the *world space* coordinates of p? (8 points)

Name or initials:

7. Discuss the depth buffer (z-buffer) algorithm.

a) Describe the algorithm. Write down pseudo-code for it. (3 points)

b) What is its purpose? (1 point)

c) How is it implemented? (2 points)

d) What are its advantages over competing algorithms? (2 points)

e) What are its disadvantages relative to competing algorithms? (2 points) (Be specific about what competing algorithms you are discussing.)

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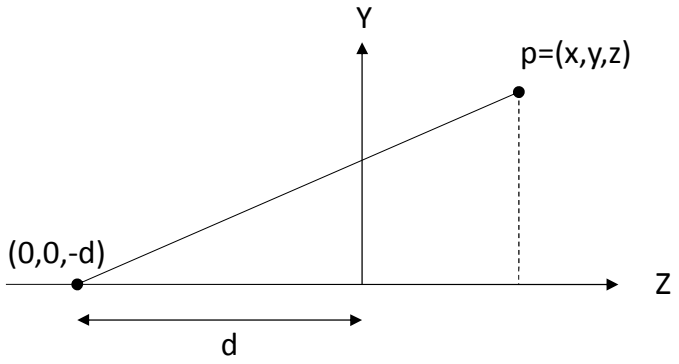
8. In class we constructed a 4x4 projection matrix which performed perspective projection along the Z axis onto a view plane at Z = d for a viewpoint centered at the origin (0,0,0). There are advantages to an alternative formulation in which the viewpoint is at point (0,0,-d) and the view plane is at the origin (i.e., the view plane is just the XY plane). Construct the corresponding 4x4 projection matrix. (10 points)



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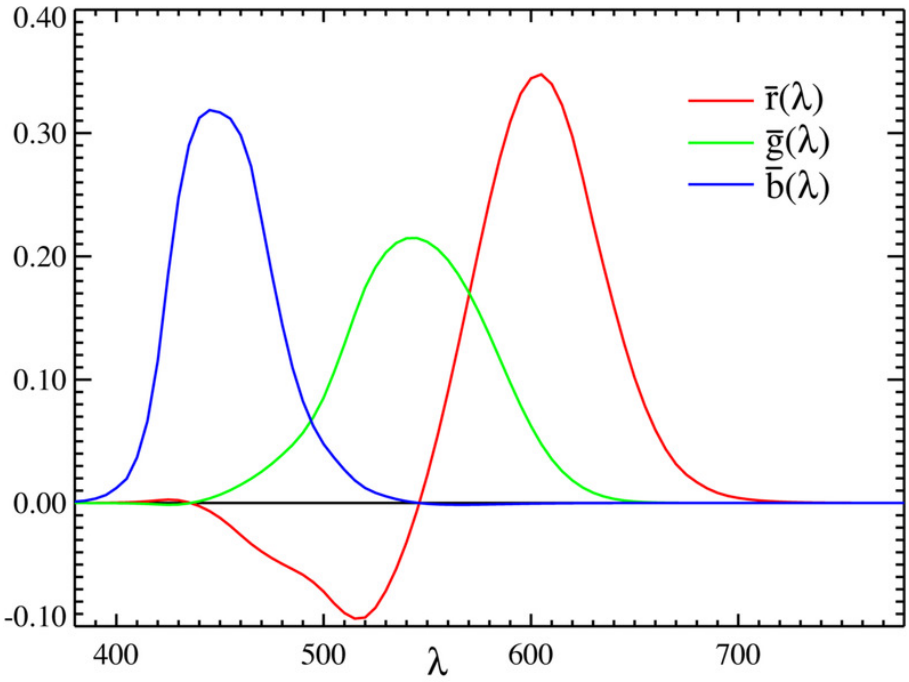
9. The figure below shows the CIE RGB matching curves. Describe how these curves were determined. Your answer should include an explanation of the meaning of the three values $\bar{r}(\lambda), \bar{g}(\lambda), \bar{b}(\lambda)$ for any given wavelength λ. It should also explain how to interpret negative values. (5-6 sentences; 10 points)



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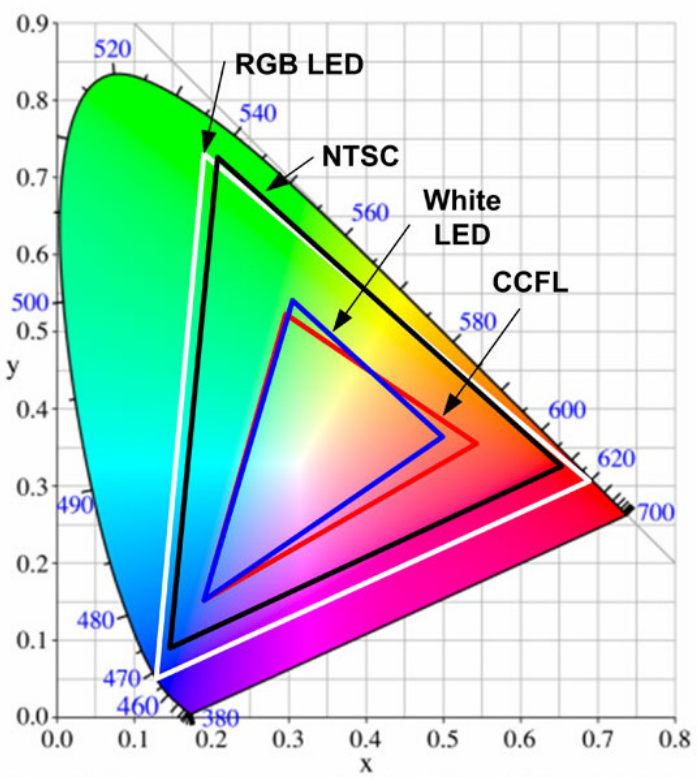
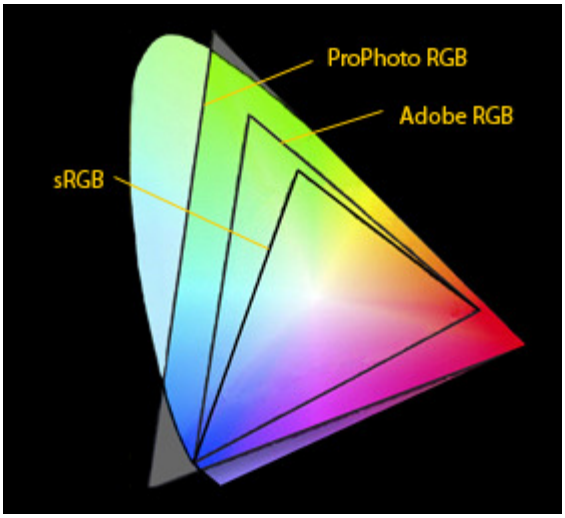
10. The figure below shows a chromaticity diagram with the color gamuts of LCDs with backlights employing CCFL (cold cathode fluorescent lamps), white LEDs and RGB LEDs in comparison with the NTSC (television) color gamut.



a) Assuming that all you knew about these display technologies were their color gamuts, which one would you prefer and why? (3 points)

b) Below is another image with color gamuts. The ProPhoto RGB gamut is the biggest of the three rectangles. What amazing feature does it have which fundamentally distinguishes it from the other two gamuts in this image, as well as those in part a)? (2 points)



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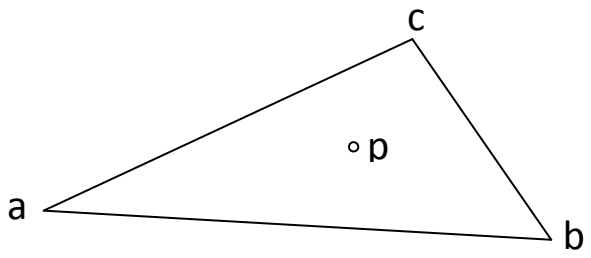
11. Given the triangle below, how is the pixel intensity at point p determined for a) Gouraud shading and b) Phong shading? No mathematical formulas are required, just a short description of the general idea and the differences between the shading methods. (6 points)

c) What are the advantages/disadvantages of Gouraud shading over Phong shading? (3 points)



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12. The Blinn shading model is given by the expression

$$c = \sum_i c_{l_i} \left(k_d \left(\mathbf{L}_i \cdot \mathbf{n} \right) + k_s \left(\mathbf{h}_i \cdot \mathbf{n} \right)^s \right) + k_a c_a$$

a) Explain the meaning of all the terms ($c, i, c_{l_i}, k_d, L_i, n, k_s, h_i, s, k_a, c_a$) in this equation. Mention for each term if it is a scalar value, a geometric vector, or if it represents a color. (5 points)

b) What values would you choose for the relevant parameters to obtain a red material with a white specular highlight? (3 points)

c) How do you increase the size of the specular highlight? (2 points)