Exam Two

CS 184: Foundations of Computer Graphics
Spring 2026
Prof. James O'Brien

Student Name:_____ **Student ID:**_____

Answers

Instructions — ***Read them carefully!***

Please read these instructions carefully before beginning the exam.

No clarifications will be given for the exam. Do not discuss the exam until solutions are released.

Allowed Resources

This is an open-book, open-notes exam. You may consult textbooks, notes, and other reference materials.

You must write all answers yourself. No other person may help you with the exam. You should not copy answers from the internet.

Use of AI Tools

You may use AI tools (such as an LLM ChatBot) ***only*** *for the following limited purposes:*

- *Locating reference materials*
- *Asking general reference questions about concepts*
- *Asking the AI whether your answer appears correct and complete*

You may ***not*** *use AI to:*

- *Write any part of an answer*
- *Rewrite, edit, or improve your answer*
- *Suggest how your answer should be corrected*

If you choose to use AI, you do so entirely at your own risk. An AI stating that an answer is correct does not guarantee that it is actually correct!

Time Limit

You should spend no more than 4 hours completing this exam.

Please fill in the you start time: _____ and end time: _____

Students with official extra-time accommodations may use their approved time. If you do so, note next to the end time above that you used your time accommodation. Do ***not*** *include any medical details or other private information.*

Writing Your Answers

Please:

- *Write legibly (if you handwrite or draw parts of the exam)*
- *Be clear and concise*
- *Show your reasoning where appropriate.*
- *If you make any specific assumptions to answer a problem, note what that they are on the test.*

Submitting the Exam

You may complete the exam in either of the following ways:

1. *Fill out the PDF digitally, or*
2. *Print the exam, write your answers, and scan the completed document*

If you wish to use a drawing tool or software to create diagrams, that is permitted.

Honor Code and Academic Integrity Certification

The Honor Code is the commitment of students individually and as a community to uphold honesty and integrity in all academic work.

By signing below, I certify that:

- *All work submitted in my name for this exam is entirely my own work.*
- *I have not received help from another person while completing this exam.*
- *I have used only the resources permitted in the exam instructions.*
- *Any use of AI tools followed the restrictions described in the instructions.*
- *I will inform course staff if I become aware of any Honor Code violations.*

I understand that making a false statement on this declaration is a violation of the Honor Code and may result in disciplinary action under the University Code of Conduct.

Your Signature: _____

Date: _____

Student ID: _____

1. Please fill in each of the blanks with an appropriate answer. If multiple possible answers exist, write the best one. Note any assumptions next to the question, separate from your answer. *2 points each blank*

1. True or False: In animation, temporal anti-aliasing is typically referred to as motion blur. ____True____
2. True of False: IK optimization based on cyclic coordinate descent produces natural human-like poses. ____False____
3. True or False: Optical motion capture systems record the position of reflective markers on the subject using ultraviolet cameras. ____False____
4. True or False: Mass and spring systems can be thought of as a form of particle system. ____True____
5. True or False: Stability problems in physical simulation only occur if double-floats are not used. ____False____
6. True or False: Feet sliding on the ground is a common problem for motion capture data, and it can create undesirable motion artifacts. ____True____
7. True or False: In a kinematic skeleton, every body must have exactly one outboard joint, but may have many inboard joints. ____False____
8. True or False: The idea of splines as a modeling tool is based on thin strips of wood, metal, or plastic that were once commonly used by engineers and designers. ____True____
9. True or False: A rotation matrix should have a negative determinant.. ____False____
10. True or False:One of the things that anti-aliasing helps prevent is the stair-step appearance of rasterized lines. ____True____
11. True or False: The Z-buffer hidden surface algorithm can be modified to account for transparency by simply adding an α-buffer. ____False____
12. True or False: The Phong reflectance model can be used to describe any real surface's reflectance properties. ____False____

13. True or False: Motion capture is often used for animating smoke, water, and other fluid phenomena. __False__

14. True or False: Path tracing is a rendering method, with many variations, that can be used to compute global illumination phenomena. __True__

15. True or False: The human eye is uniformly sensitive to all frequencies of visible light. __False__

16. True or False: Radiosity methods are suitable for rendering scenes with diffuse surfaces. __True__

17. True or False: Particles can be used to render smoke. __True__

18. True or False: Given a set of points in 3D space, a weighted average of the positions where the weights are all positive and sum to 1 will produce a new position that will be inside the convex hull of the original set of points. __True__

19. True or False: Photon maps do not work well for complex scenes because most graphics cards have limited memory for texture maps. __False__

20. True or False: Quaternions represent rotations using points on a hypersphere in four-dimensional space. __True__

21. True or False: All fluid simulations must use Eulerian formulations. __False__

22. True or False: Fluid simulations using staggered grids (also called Mac or Yee grids) store velocity components on the boundary between grid cells. __True__

23. True or False: Semi-Lagrangian Advection is a stable way of computing advection. __True__

24. True or False: The Ks parameter in spring and mass systems is the square-root of the Ks that appears in shading calculations. __False__

25. True or False: The Jacobian of a valid kinematic system will always be invertible. __False__

26. True or False: Ambient occlusion tends to enhance the appearance of surface detail. True

27. True or False: In a smoke-filled room the radiance along a straight line would fall off exponentially. True

28. True or False: The rods in the human eye have a spectral response function that peaks somewhere between the short and long cones' responses. True

29. True or False: Some motion capture systems use magnetic fields to determine the location and orientation of tracker objects. True

30. True or False: Raytracing can be accelerated using BSP-Trees or K-D Trees. True

31. True or False: Cloth can be modeled in a perfectly realistic way using a collection of particles attached by springs. False

32. True or False: Radiance grows with the square of distance along a straight line in free space. False

33. True or False: Motion capture systems typically run at rates between 20 and 30 samples per second. False

34. True or False: The "Animation Principles" developed by hand animators are all based on physical laws. False

35. True or False: The sky is blue because photons in the red-orange parts of the spectrum are scattered by nitrogen atoms.. False

36. True or False: The result of applying subdivision to a cubic curve is four quadratic curves. False

37. True or False: Magenta between red and blue on the visible spectrum. False

38. True or False: Turning your final assignment in late will result in a zero on the assignment! True

2. **Imagine that you have an analog display (for example, a CRT monitor) where the lines for red and blue have been swapped. If you tried to display the following colors what would you actually see on the screen? (Assume an RGB additive model with no gamma.)**

16 points

Red	Blue
Green	Green
Blue	Red
Magenta	Magenta
Cyan	Yellow
Yellow	Cyan
Black	Black
White	White

3. **Give two examples of phenomena that require a global illumination model for them to be rendered properly.** *10 points*

Many possible answers.

4. **A friend of yours tells you that they have a method for computing an analytical inverse to any kinematics equation. Give a succinct reason why this claim is very unlikely to be true. (Claiming you have no smart friends is not a valid answer.)** *8 points*

Lots of possible reasons about functions and difficulty of inverting them. Also, pointing out the existence of multiple solutions and/or situations with no solution.

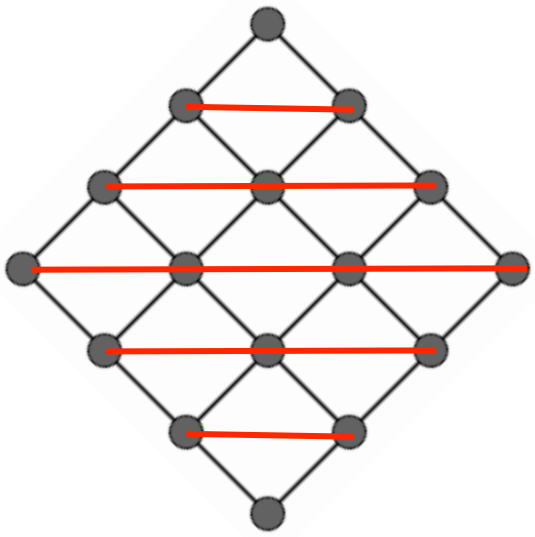
5. **Consider a surface is defined parametrically by x = x(u). Write the formula for the unit length surface normal at a given point, u0. (Note that x and u are vectors.)** *6 points*

```
n = normalize(cross( d x / d u1 , d x / d u2 )

Note assuming u in R2 because it's a "surface".
The expressions for dx / d ui are evaluated both
at u = u0.
```

6. **Consider a surface is defined implicitly by f(x) = 0. Write the formula for the unit length surface normal at a given point on the surface, x0. (Note that x is a vector.)** *6 points*

```
n = normalize(grad(f(x),x,x0))

where grad(f(x),x,x0) means take the gradient of
f(x) w.r.t. to x and then evaluate the resulting
expression at x = x0.
```

7. **On the spring/mass diagram below, draw springs that could be added for the structure to resist shear.** *6 points*

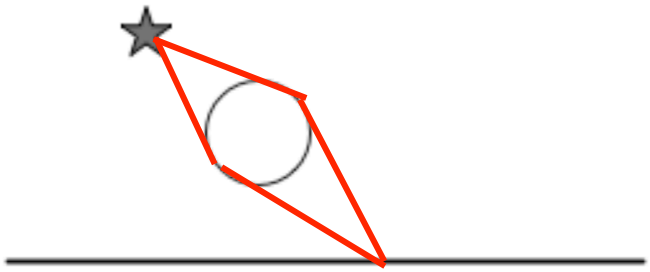


Vertical or vertical and horizontal together are also answers.

8. **Write out a parametric equation for a plane in 3D that is normal to the Y axis and passes through some point P.** *4 points*

```
x(u,v) = P + u * X_axis + v * Z_axis
```

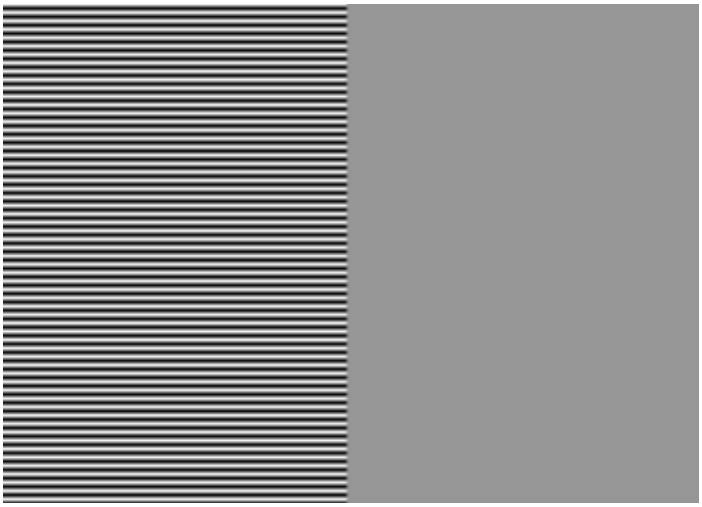
9. **In the diagram below of a light source, a clear glass ball, and a diffuse surface, draw lines illustrating the path traveled by light to form a refraction caustic on the surface.** *4 points*



10. **Imagine that you are ray-tracing a scene to test rendering code that you have written. The test scene contains a colorless glass slab floating inside a closed light-blue room (walls, floor, ceiling are all light blue). Every inch of the room is well lit by white light. You notice that many of the the pixel values in the resulting image are black, appearing like black spots scattered over the glass slab. Explain a likely cause for this error and how it could be fixed.** *8 points*

Shadow "acne" happens when floating point error causes a ray from a surface to incorrectly intersect the same surface. A shadow bias (setting the min T-value to be +epsilon instead of zero) often fixes the problem.

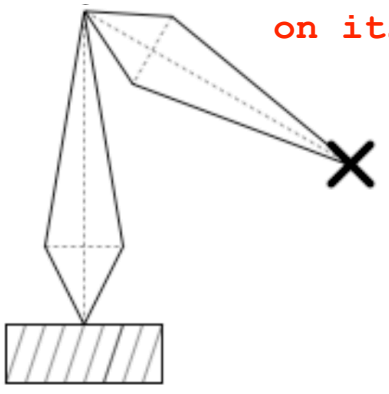
11. Consider the following image with alternating white/black lines on the left and 50% gray on the right. If a person is standing far enough away from the monitor that the black and white lines blur evenly together, then what does it most likely mean if one side looks brighter or darker than the other side? *10 points*



Display needs gamma correction / calibration

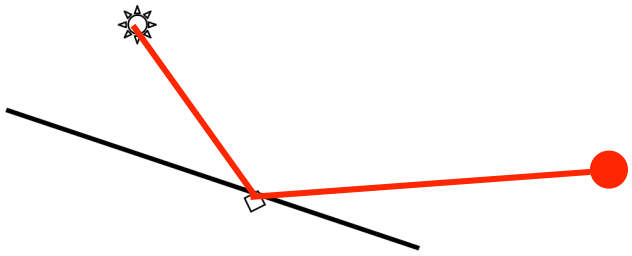
12. In the context of doing inverse kinematics problems, when is the Jacobian singular? Draw an example using a two-link arm whose links are connected by a rotation join and whose root link is attached to ground/base with a rotation joint. Make sure your diagram is clear. Use an X to indicate the goal point. *8 points*

Arm out straight, or bent back 180 degrees on itself.



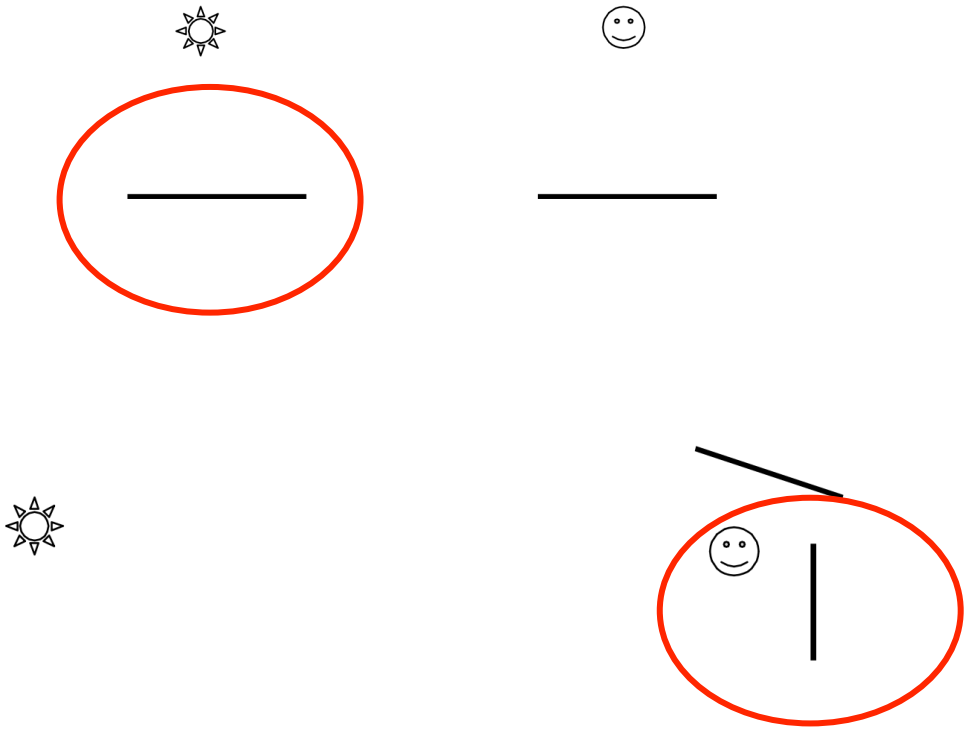
Example figure

13. Consider the diagram below. A location has been marked on the surface. Indicate a viewer/eye position such that a viewer looking at the surface from that position would see a bright specular highlight on the surface at the marked location. (Assume that the Phong shading is being used.) *6 points*

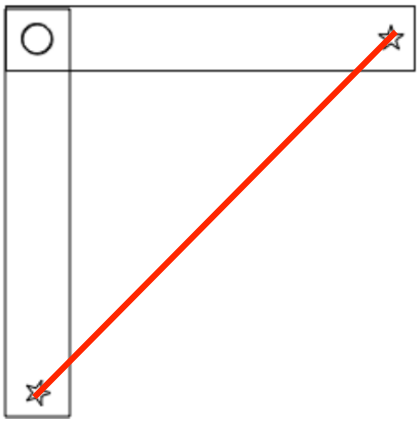


Bounce ray is reflected about the normal.

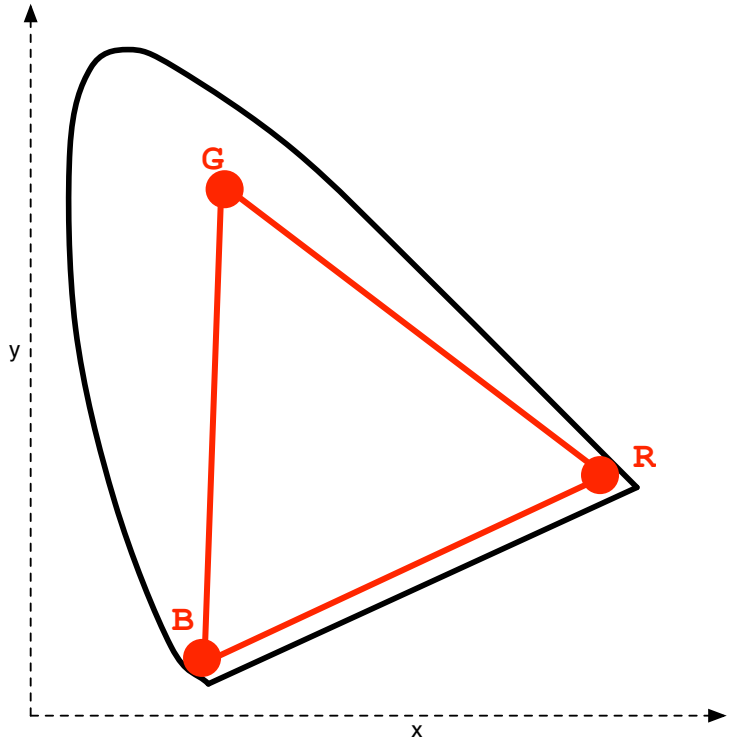
14. Consider the two diagrams below. All four surfaces are identical ideal diffuse reflectors. In each diagram circle the surface that will appear brighter from the indicated observer location. *8 points*



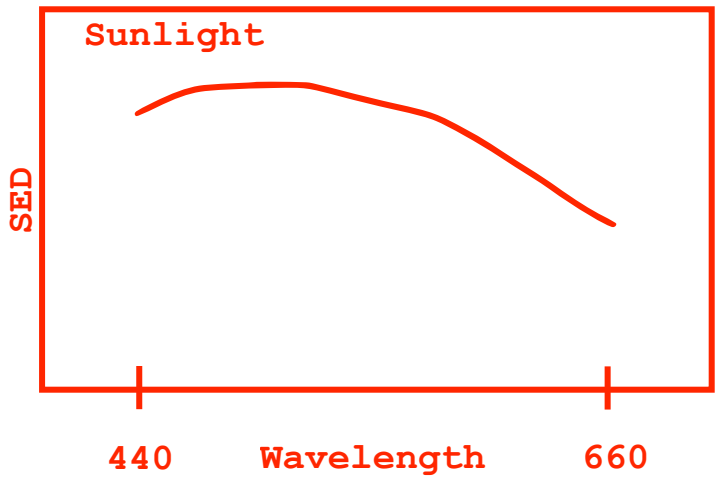
15. Below is a diagram showing a bar that has been rotated 90 degrees about the point indicated with a circle. If intermediate positions were generated by *linearly interpolating the transformation matrices*, how would the point indicated by the star move? Give your answer by drawing the path of the star.. *8 points*

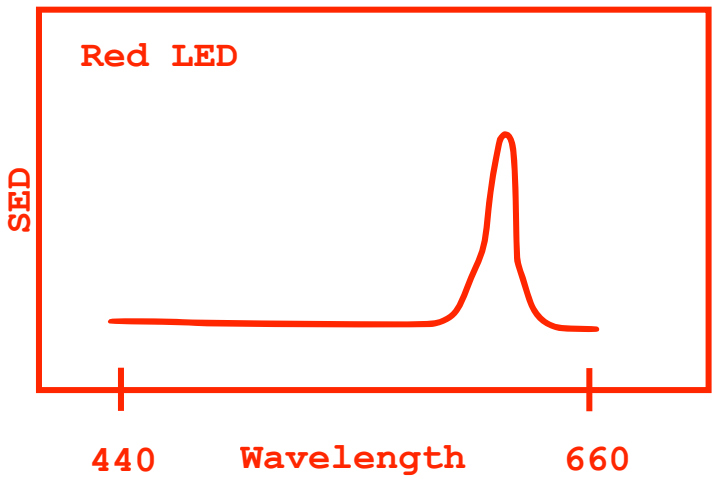


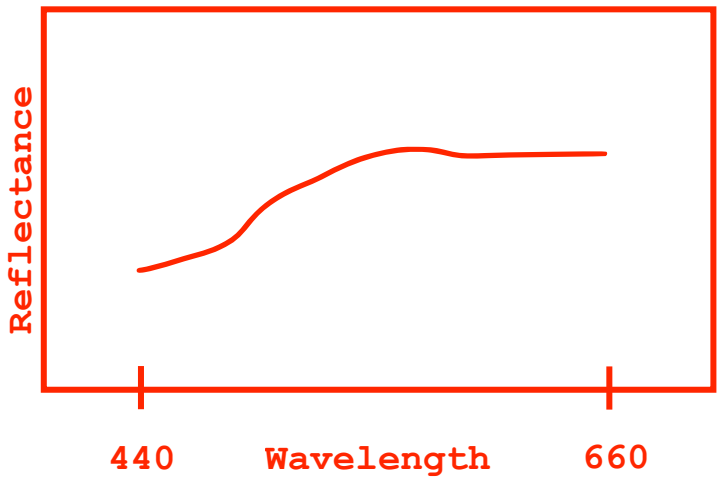
16. The following diagram shows the the x-y plane of the CIE color space. Mark and label one plausible location each for red, green, and blue primaries / basis colors. Indicate the color gamut for the color basis you have shown. *12 points*

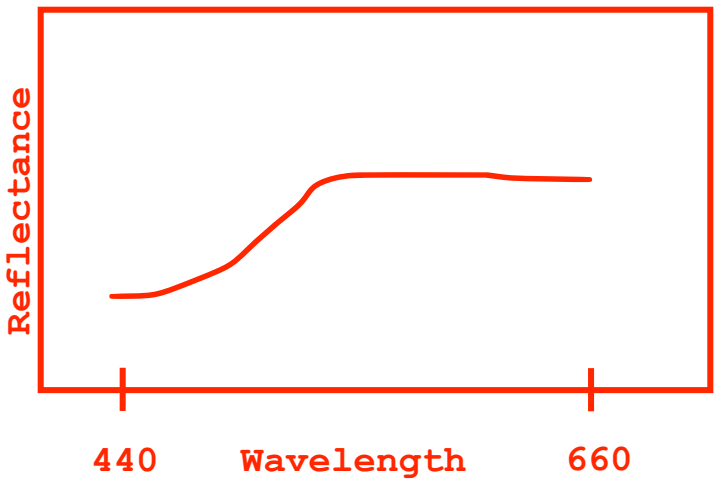


17. Draw an graph of the spectral density functions for two light sources, sunlight and a red LED. Then draw a two more graphs of the spectral reflectance functions of a pair of materials that appear different colors under sunlight, but the same color in the red LED light. Your graphs do not need to be perfect, but they should be qualitatively reasonable and illustrate the situation clearly. Label the axes of your graphs. *16 points*









18. Experimental AI administered question! *16 points*

While logged in to you Cal gmail account, open this link and start a chat with the Gemini "Gem":

https://gemini.google.com/gem/1rRC4ry_4rqV6dUgIKOimg2clAb2iw1zQ?usp=sharing

When you have completed the question successfully, enter the Verification Code below.

Verification code: _____

19. What did you think of the AI administered question? *5 points,*
Points are just for completion, not content. And your feedback is very much appreciated!