CMSC 435 Final Exam (Fall 2016)

Instructions: Clearly write your name on this sheet. Answer each problem in the space provided. If you need extra space, clearly write your name and the problem number on an extra sheet of paper, write on extra sheet in the answer space on the exam paper, and turn in the extra sheet with your exam.

Write legibly. If the person grading the test cannot read something, s/he will simply assume that you meant the illegible portion as a note to yourself and they will ignore it. If you lose points because part of your answer could not be read, you will not be given the opportunity to explain what it says!

Be clear and concise. The answers to most questions should be short. If you find yourself writing an excessively long response, you may want to think more carefully about the question. Long rambling answers generally get fewer points that short ones do because there are more opportunities to mark something wrong.

You may use any existing resource to complete the exam, including your notes, the textbook, and online materials. You may also email questions to the professor, especially for clarification, and he may choose to make posts to piazza, but please do not post to piazza regarding the exam. However, your exam must represent your own work. You may email questions to the professor, especially for clarification, and he may choose to make posts to piazza. You may not discuss the exam with anyone, either in person or virtually through bulletin boards or discussion sites. You may not ask questions of other students, look at another student's exam. In summary: do not cheat. Persons caught cheating will be subject to disciplinary action.

Each question is marked with a number of points. There are 170 points total.

If something isn’t clear, you will have an opportunity to ask questions during class on Monday, December 12.

Exams are due by 3pm Wednesday December 21. If you cannot find me in person, you may slide them under my office door, ITE 341.

Good luck

Name: ____________________________

GL Login: ____________________________

Secret Code Name for Spreadsheet (if desired): ____________________________
True/False and Fill in the Blank.

1. (1 pt) True/False: Axis-aligned bounding boxes at the same level of a bounding volume hierarchy do not overlap. ____________

2. (1 pt) True/False: In a spatial subdivision, each point in space belongs to exactly one node, whereas objects may belong to many nodes. ____________

3. (1 pt) True/False: Convolution is commutative. ____________

4. (1 pt) ____________ computes joint angles that move an end effector to a desired goal position.

5. (1 pt) True/False: Interpolating rotations by interpolating Euler angles results in high-quality animation. ____________

6. (1 pt) ____________ is the process that produces render geometry given skeletal motion.

7. (1 pt) ____________ refers to acquiring motion of an actor in a studio for use in virtual scenes.

8. (1 pt) ____________ refers to two different colors that appear the same under questionicular lighting conditions.

9. (1 pt) True/False: Eulerian methods use a fixed reference frame. ____________

10. (1 pt) True/False: Radiance is constant along straight lines. ____________

11. (1 pt) ____________ refers to the process of creating a 24-bit image from a high dynamic range image.

12. (1 pt) Moire patterns are an example of ____________.

13. (1 pt) The Fourier transform of a box filter is a ____________.

14. (1 pt) The Fourier transform of a Gaussian filter is a ____________.

15. (1 pt) A ____________ perturbs surface normals to give the illusion of fine-scale geometry.

16. (1 pt) True/False: Indirect lighting tends to be smooth. ____________

17. (1 pt) When light passes through a refractive surface it may be focused to create a ____________.

18. (3 pts) The three components of Phong’s illumination model are ____________, ____________, and ____________.

19. (1 pt) ____________ maps are created by rendering the scene from a light source.
20. (1 pt) More repeated knot values will cause a non-uniform cubic B-spline to interpolate a control point.

21. (1 pt) The property means that a curve does not cross a line more than its control polygon does.

22. (1 pt) Guarantees that translating, scaling, rotating, or skewing the control points of a curve is the same as performing those operations on the curve itself.

23. (1 pt) Bezier curves are bounded by the of its control points.

24. (1 pt) The convolution of two box filters is a function.

25. (1 pt) The result of convolving a signal $f(x)$ with the dirac delta yields .

26. (1 pt) The integral of the dirac delta is .

27. (1 pt) Convolving box filters results in the B-spline filter.

28. (1 pt) A continuous filter is if it will reconstruct a constant sequence as a constant function.

29. (1 pt) A is a binary tree that indexes spatial data according to axis-aligned planes.

30. (1 pt) A is a binary tree that indexes spatial data according to arbitrary planes.

31. (1 pt) A mesh may be smoothed by repeatedly applying the operator to get a direction to move the meshes vertices.

32. (3 pts) The singular value decomposition guarantees that all $3 \times 3$ transformation matrices can be decomposed into a followed by a , followed by a .

33. (1 pt) A useful property of light is —the effect caused by more than one light source is simply the sum of the effects of the light sources individually.

34. (2 pts) RenderMan performs vertex shading after polygons into small quadrilaterals called .

35. (1 pt) When tracing shadow rays we search for intersections in the interval $t \in [\epsilon, l]$ where $\epsilon$ is the and $l$ is the distance to the light.

36. (1 pt) True/False: I am looking forward to winter break.
For the next three questions, assume you have a triangle with vertices $A, B, C$, where the vertices are given in counterclockwise order.

37. (2 pts) Give an equation for the unit-magnitude normal for the triangle.

38. (2 pts) Give an equation for the area of the triangle.

39. (2 pts) Give a parametric equation of the triangle in terms of parameters $(u, v)$.

40. (10 pts) Find the basis functions that allow you to specify a quadratic curve that has endpoints $p_0$ and $p_1$ and has first derivative $p_2$ at the endpoint $p_1$. More specifically, find quadratic polynomials $b_0(u)$, $b_1(u)$, $b_2(u)$, such that the curve $p(u) = b_0(u)p_0 + b_1(u)p_1 + b_2(u)p_2$, has $p(0) = p_0$, $p(1) = p_1$, and $p'(1) = p_2$. 
41. (6 pts) List three (3) desirable properties of a piecewise cubic polynomial (not including that each piece be cubic).

42. (1 pt) Which of these properties does the *Natural Cubic* fail to satisfy.

43. (1 pt) Which of these properties does the *Hermite Cubic* fail to satisfy.

44. (1 pt) Which of these properties does a *B-spline* fail to satisfy.
45. (5 pts) Use the geometric de Casteljau algorithm to find the point at \( u = 0.25 \) on the cubic Bezier curve given by the control polygon in the figure below. Hint: this will involve drawing 3 carefully chosen line segments.

46. (5 pts) Subdivide the control polygon for the Bezier curve below. The result should be two control polygons.

47. (6 pts) Show the topological split for the Loop (left) and Catmull-Clark (right) subdivision schemes.
48. (6 pts) List the three flocking forces in Reynolds’ Boids model.

49. (4 pts) Give equations to update the velocity, \( v \), and position, \( x \), of a particle experiencing a force, \( f \), over a timestep, \( \Delta t \).

50. (4 pts) In the equation below, circle the advection term and draw a rectangle around the viscosity term.

\[
\frac{\partial u}{\partial t} = \frac{\mu_e}{\rho} \nabla T - \frac{\nabla p}{\rho} + \frac{\mu_v}{\rho} (\nabla^T \nabla) u + \frac{f}{\rho} - (u^T \nabla) u
\]  

(1)
51. (5 pts) Convolve the filter

\[
\begin{bmatrix}
1 & 2 & 1
\end{bmatrix}
\]

with the discrete 1-dimensional signal

\[
\begin{bmatrix}
4 & 5 & 2 & 4 & 3 & 2 & 0
\end{bmatrix}
\]

Ignore the boundaries (your answer should be 5 numbers).

52. (4 pts) What is the Fourier transform and why do we care? (be brief)

53. (4 pts) What is aliasing and how do we combat it? (again, be brief)
54. (2 pts) What is stratified sampling?

55. (2 pts) What is a scene graph? (be brief, no more than two sentences)

56. (2 pts) What auxiliary data structure is especially useful when traversing a scene graph?
57. (5 pts) Write pseudocode to print the ids of the faces incident to a vertex $v$ using the following half-edge data structure

```plaintext
HEdge {
    HEdge pair;
    Hedge next;
    Vertex v;
    Face f;
    int id;
}

Face {
    HEdge h; // any h-edge of this face
    int id;
}

Vertex {
    HEdge h; // any h-edge pointing toward this vertex
    int id;
}

FacesOfVertex(v) {
    // Pseudocode to print ids of faces incident to vertex v
}
```

58. (6 pts) Consider two 2D triangles, the first with vertices at $(0, 0)$, $(1, 0)$, and $(0, 1)$ and the second with vertices at $(4, 3)$, $(2, 3)$, $(-1, 2)$. Draw the axis-aligned bounding box hierarchy, in each of the three nodes give the extent of each bounding box (formatted as $(x_0, y_0) \times (x_1, y_1)$).
59. The following six questions refer to the transport or rendering equation

\[ L_s(k_{io}) = \int_{\text{all } k_i} \rho(k_i, k_{io}) L_f(k_i) \cos \theta_i d\sigma_i \]  

(2)

60. (1 pt) What is \( L_s \)?

61. (1 pt) What is \( k_i \)?

62. (1 pt) What is \( \rho \)?

63. (1 pt) What are the (physical) units of \( \rho \)?

64. (1 pt) What are the (physical) units of \( L_s \)?

65. (1 pt) Why is there a \( \cos \theta \) term?
66. (2 pts) How does surface radiance differ from field radiance?

67. (2 pts) What is the primary assumption underlying the radiosity algorithm?

68. (2 pts) What is a gamut?

69. (2 pts) What do most color spaces represent colors with three channels?
70. (2 pts) What makes the L*a*b* color space special?

71. (2 pts) Why is it reasonable to associate the energy of a pixel with a local estimate of the gradient?

72. (3 pts) Write down the recurrence for the cost of a seam that will remove a row of pixels.

73. (2 pts) How do you create a high dynamic range image?
74. (6 pts) Briefly and carefully describe the two-pass photon mapping algorithm for global illumination. Where do rays originate and what is computed and stored in each pass?

75. (15 pts) Fill out the course survey at https://www.surveymonkey.com/r/KCMNFWY. What is the last question of the survey?