Exam Instructions (Read Carefully)

1. Print your Name and Student Identification Number on every page of the exam in the space provided at the top of each page immediately.

2. Sign the first page of the exam with your Signature in the space provided on the upper left immediately.

3. Continue reading the instructions, but do not open the exam booklet until you are told to do so by a proctor.

4. Cheating is an academic offense. Your signature on the exam indicates that you understand and agree to the University's policies regarding cheating on exams.

5. Please read the entire exam before answering any of the questions.

6. There are five questions on this exam, each worth the indicated number of marks. Answer as many questions as you can.

7. Write all of your answers on these pages. If you need more space, there is blank space at the end of the exam. Be sure to indicate when a question is continued, both on the page for that question and on the continuation page.

8. Interpret the exam questions as written. No questions will be answered by the proctors during the exam period.

9. The exam is closed book. You may not use any aids.

10. You have 2.5 hours in which to work. Budget your time wisely.

11. In the event of a fire alarm during the exam, enter the four-character code provided by the proctor(s) in the space on the upper right, then gather your belongings and exit the room, handing your exam to a proctor as you exit.

12. No one will be permitted to leave the exam room during the last ten minutes of the exam.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mark</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>1(a)</td>
<td>10</td>
<td></td>
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<tr>
<td>1(b)-(d)</td>
<td>16</td>
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<tr>
<td>2(a)-(c)</td>
<td>12</td>
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<tr>
<td>2(d)-(g)</td>
<td>16</td>
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<tr>
<td>3(a)-(b)</td>
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<td>4(a)</td>
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<td>4(b)-(e)</td>
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<td>5(a)-(f)</td>
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<td>5(g)-(m)</td>
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<td>5(n)-(t)</td>
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<td>5(u)-(aa)</td>
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<td>Total</td>
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Question #1 [26 marks total]
This question tests your knowledge of the hardware components of a cathode ray tube (CRT).

(a) [10 marks] Draw a schematic diagram of a monochrome (black-and-white) CRT and include a brief description of the major components (the diagram in the text described nine components, your diagram might have a few more or a few less and still be a satisfactory answer to the question).
(b) [6 marks] Three of subsystems that were part of your answer to Part (a) involve the use of force fields to alter the motion of the electrons within the CRT after the electrons pass the control grid. Fill in the following table to indicate which of these subsystems might use electrostatic fields and which might use electromagnetic fields − write “Yes” or “No” in each box.

<table>
<thead>
<tr>
<th>Subsystem (write the name)</th>
<th>Electrostatic (Y/N)</th>
<th>Electromagnetic (Y/N)</th>
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</table>

(c) [5 marks] Draw a timing diagram (similar to Figure 1.9 in the text, which was discussed in lecture) for the horizontal deflection signal and for the vertical deflection signal of an interlaced television display. You may assume the signal is RS-170 timing, which is what NTSC uses. Include in your diagram an indication of the approximate numbers of visible and invisible scan lines and the approximate timing for fields.

d) [5 marks] Describe the additional components (or modifications to existing components) present in a colour CRT that are not required in a monochrome CRT. Are there any other significant differences between a colour CRT and a monochrome CRT?
Question #2 [28 marks – 4 marks each]
This question tests your knowledge of Alias\wavefront StudioPaint and StudioDesign (the modeling software) as they were used in the tutorials.

(a) For each of the following colour selection techniques, indicate whether the technique is available in StudioPaint and, if it is available, give a brief description of how you select a colour using it. Write “Yes” if it is available, “No” if it is not.

   HSV –

   *four-way linear interpolation between user-selected colours –*

   CIE XYZ –

   *using painting tools to blend colours directly in an auxiliary image or the current image –*

   *tristimulus response functions for the cones –*

(b) For what reason would you paint with a clone brush in StudioPaint?

(c) What tool is used to “zoom in” on an area of an image in StudioPaint?
(d) What tool in StudioPaint is used to view different parts of an image when the image is too large to see all of it at the current zoom factor?

(e) What is the effect of having a pivot point in Alias StudioDesign?

(f) What is the name of the operation in StudioDesign after which all subsequent transformations assume a single pivot point for a collection of objects?

(g) What “graphical inventory” visualization format in StudioDesign most closely corresponds to the concept of a DAG that we discussed in lecture?
Question #3 [18 marks total]
This question tests you knowledge of hierarchical display list structures as discussed in lecture.

Below is a DAG that will display multiple instances of the cube stored in the node “C” when the Walk() algorithm is used on it. Refer to this diagram for both parts of this question.

The nodes with a “T” label are translations.
- “T0” is the translation that takes \((x, y, z)\) to \((x, y - 4, z)\).
- “T1” is the translation that takes \((x, y, z)\) to \((x, y, z)\).
- “T2” is the translation that takes \((x, y, z)\) to \((x, y + 4, z)\).
- “T3” is the translation that takes \((x, y, z)\) to \((x - 4, y, z)\).
- “T4” is the translation that takes \((x, y, z)\) to \((x, y, z)\).
- “T5” is the translation that takes \((x, y, z)\) to \((x + 4, y, z)\).

The “R” node is a counterclockwise rotation of 45 degrees about the \(x\) axis, and the “S” node is a scaling that expands everything by a factor of two along the \(x\) axis, contracts everything by a factor of three along the \(y\) axis, and leaves things unchanged along the \(z\) axis.
(a) \[3\text{ marks}\] How many cubes will be drawn on the screen when this DAG is traversed by the Walk() algorithm described in lecture?

(b) \[15\text{ marks}\] Assume that the viewing transformation is just the identity matrix with no perspective. Show the contents of the matrix stack when the final cube is being drawn on the screen as the data structure is walked according to the Walk() algorithm described in lecture. The stack will contain five \(4\times4\) matrices with the current transformation on the top of the stack – you should show all of the numeric entries in each of the matrices. Do not use symbolic entries, although you can use unevaluated square roots (but not trigonometric functions).
Question #4 [24 marks total]
This question has a number of parts. It tests your knowledge of implicit surfaces in general and quadric surfaces in particular for properties required in the ray-tracing assignment. Not all parts of the question depend on each other, so make sure that you answer as many parts of the question as possible even if you do not answer all parts.

The general implicit equation for a surface is given by
\[ S(x, y, z) = 0. \]

A normal vector to the surface at any point on the surface defined by this equation can be computed as the gradient of \( S \),
\[
\nabla S = \left( \frac{\partial S}{\partial x}, \frac{\partial S}{\partial y}, \frac{\partial S}{\partial z} \right)
\]

The components of the normal (the gradient) are just the partial derivatives of the implicit function that defines the surface.

(a) [5 Marks] A surface is a quadric iff its implicit function \( S \) has the special form
\[ S(x, y, z) = Ax^2 + By^2 + Cz^2 + 2Dxy + 2Eyz + 2Fxz + 2Gx + 2Hy + 2Jz + K. \]

Write the closed-form expression for the gradient of \( S \) when \( S \) is a quadric. Your answer should not contain any unevaluated derivatives. The gradient should be expressed entirely in terms of the three variables \( x, y, \) and \( z \) and the coefficients \( A \) through \( K \) of the quadric.
(b) [5 Marks] The quadric surface defined by the implicit function $z^2 = x^2 + y^2$ defines a **double-ended cone** (often called a “bi-conal surface”) whose central axis lies along the $z$-axis with circular cross sections parallel to the $xy$-plane whose radii are equal to the magnitude of the $z$-coordinate. The tips of the two cones comprising the bi-conal surface touch at the origin. In the general case, a bi-conal surface results from rotations, scalings and translations of this basic double-ended cone.

Give the coefficients of the quadric that defines a bi-conal surface with a circular cross section whose central axis is the line parallel to the $x$-axis through the $(x, y, z)$ point $(0, 7, 5)$ and which contains the three points $(2, 7, 6)$ and $(4, 7, 6)$ and $(6, 7, 8)$ on its surface. Orient your equations so that points “outside” the double-cones are positive and points “inside” are negative.

(c) [5 Marks] Combining your answers to Parts (a) and (b), write the closed-form expression for the gradient of the bi-conal surface in Part (b) expressed entirely in terms of the variables $x, y$ and $z$ and numeric coefficients.

(d) [5 Marks] Using your answer to Part (c), determine the **unit normal** to the bi-conal surface defined in Part (b) at the point $(2, 7, 6)$.

(e) [4 Marks] Finally, show the result of using the same technique as in Part (d) at the point $(3, 7, 5)$ and explain why the result is not a unit normal to the surface at that point.
Question #5 [54 marks – 2 marks each]
Explain the following terms as they have been used so far in our course on computer graphics. If the term is an acronym, explain for what it is an acronym and its meaning, usage, or how it functions (i.e., do not just provide the full name, but also explain what the acronym identifies). If the term is a person’s name, describe at least one important thing the person contributed to the field of computer graphics.

(a) ambient light

(b) calligraphic display

(c) cones and rods

(d) Fitts’s Law

(e) fluorescence

(f) Frenet frame
(g) keyframe animation

(h) Mach band

(i) motion path animation

(j) non-spectral colour

(k) NTSC

(l) NURBS

(m) outcode
(n) persistence

(o) point at infinity (in 3-D)

(p) refresh rate

(q) simultaneous contrast

(r) special orthogonal matrix

(s) update rate

(t) viewport
(u) winged edge data structure

(v) for all $a, b \in F$ and $u, v \in V$, $T(au + bv) = aT(u) + bT(v)$

(w) Jack Bresenham

(x) Daniel Cohen

(y) Douglas Engelbart

(z) James Foley

(aa) Ivan Sutherland