Exam Instructions (Read Carefully)

1. Sign the first page of the exam with your Signature in the space provided on the upper left immediately.
2. Continue reading the instructions, but do not open the exam booklet until you are told to do so by a proctor.
3. Print your Name and Student Identification Number on every page in the space provided at the top of each page before you start the exam.
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 four 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. There are no aids permitted except for a calculator.
10. You have 2 and 1/2 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>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1(b)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3(a-b)</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>3(c-e)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>3(f)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>4(a-f)</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4(g-m)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>4(n-t)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>4(u-aa)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>
Question #1 (40 marks – 2 marks each)
This question tests your knowledge of light, human colour vision, colour systems, and CRTs.

For each of the following, check the appropriate box to indicate whether the statement is generally True or generally False. Wrong answers count negative, so don’t guess.

**True**  **False**  **Statement (+2 for correct answers, −2 for incorrect)**

[ ] [ ] The **spectrum** of a light source determines the colour that will be perceived by a human viewer under controlled viewing conditions.

[ ] [ ] The **energy** (voltage) of the electron beam in a CRT determines the colour of the light that will be emitted by the phosphor on the face of the CRT.

[ ] [ ] In the human visual system, the **luminance** of a colour is largely dependent on the response of the red and green cones, and much less dependent on the response of the blue cones.

[ ] [ ] Each type of phosphor in a CRT has a only a single wavelength that is emitted during **phosphorescence**.

[ ] [ ] Each type of phosphor in a CRT has a only a single wavelength that is emitted during **fluorescence**.

[ ] [ ] CRTs that were used with lightpens in line-drawing systems often had **doping** in the phosphor to provide short persistence “spikes” in the light produced by the phosphor.

[ ] [ ] In the human visual system, the **red cones** are not sensitive to photons of green light.

[ ] [ ] The conversion between the **CIE XYZ colour system** and the **monitor RGB colour system** is a linear transformation.

[ ] [ ] Two spectral distributions that are perceived to be the same colour are called **metamers**.

[ ] [ ] All **pure** colors are **spectral** colors because they have a **dominant wavelength**.
True  False  Statement (+2 for correct answers, −2 for incorrect)

[ ] [ ] The persistence of a phosphor is the time it takes for phosphorescence to decay to 10% of its original intensity.

[ ] [ ] The pitch of a CRT is the spacing between pixels as measured on the screen.

[ ] [ ] High performance CRTs, such as those used in line drawing displays or film recorders, often employ more expensive electrostatic deflection systems to obtain better speed and accuracy, but most monitors use the cheaper electromagnetic deflection systems.

[ ] [ ] The accelerating system is always electromagnetic, never electrostatic.

[ ] [ ] A standard color CRT has multiple electron guns and a shadow mask, but a black and white CRT does not.

[ ] [ ] The source of electrons in a CRT is the cathode, which produces electrons when heat from the filament is applied to it.

[ ] [ ] The update rate is always at least as fast as the refresh rate for a CRT.

[ ] [ ] Monitors for computer graphics are more expensive than regular television sets because the difficult-to-manufacture (and thus very costly) phosphors used for computer graphics must provide a gamut that contains the entire CIE chromaticity diagram.

[ ] [ ] A delta-delta CRT is much easier to keep in alignment and is easier to manufacture than a precision in-line delta CRT.

[ ] [ ] A standard interlaced CRT must have an odd number of scan lines or else the even and odd fields will overlap each other instead of interlacing with each other.
Question #2 [25 marks total]
This question tests your knowledge of ray tracing and related concepts in Assignment #3.

Draw a diagram to illustrate the basic phenomena in ray tracing and give a brief description of the various elements of your diagram. Be sure to include information on primary rays, reflection, refraction, secondary rays, shadows, Snell’s law, and transparency in your answer.
Question #3 (31 marks)
This question tests your knowledge of the 3D Hermite curves used to define the path for a generalized cylinder in Assignment #4.

All parts of this question refer to the path defined by the following three control points that define two Hermite segments, one segment defined by the first two control points and a second segment defined by the last two control points. The control points are used to compute the $P_i$ and $R_i$ values for the Hermite curve.

<table>
<thead>
<tr>
<th>control points</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>first</td>
<td>0.0</td>
<td>0.0</td>
<td>2.0</td>
</tr>
<tr>
<td>second</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>third</td>
<td>1.5</td>
<td>−1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

(a) [5 marks] The $P_i$ used to define the Hermite curve are the control points themselves. How are the $R_i$ defined in terms of the $P_i$ for Assignment #4? Be sure to explain any special cases, such as the first and last $R_i$ values if they differ from the general case.

(b) [4 marks] How many of the control points are interpolated by the Hermite segments?
(c) [8 marks] For the two Hermite segments defined by the control points in the table on the previous page, fill in the table below with the $P_i$ and $R_i$ geometry values that would be computed using the assumptions in Assignment #4.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Geometry</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>first segment</td>
<td>$P_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>first segment</td>
<td>$P_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>first segment</td>
<td>$R_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>first segment</td>
<td>$R_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>second segment</td>
<td>$P_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>second segment</td>
<td>$P_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>second segment</td>
<td>$R_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>second segment</td>
<td>$R_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(d) [3 marks] What is the tangent vector (the first derivative) at the second control point?

(e) [3 marks] What is the unit tangent vector at the second control point?
(f) [8 marks] What is the cubic polynomial $y(t)$ for the first segment of the path? (Show your work to get partial marks!)
Question #4 (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). Where appropriate, include explanatory diagrams or formulae in your answers.

(a) ambient light

(b) \[ Ax + By + Cz + D = 0 \]

(c) cones

(d) dolly

(e) Frenet frame

(f) glPopName()
(g) glPushMatrix()

(h) GLUT

(i) Gouraud shading

(j) Ivan Sutherland

(k) linear transformation

(l) Newell’s formula

(m) normalized planar equation
(n) NURBS

(o) Phong illumination model

(p) pivot point

(q) point at infinity

(r) \[ P(t) = (1 - t) \cdot P_0 + t \cdot P_1 \]

(s) quadric surface \[ \text{[give the general formula]} \]

(t) right-handed coordinate system
(u) rods

(v) synthetic camera analogy

(w) tumble

(x) vertical retrace

(y) viewport

(z) window

(aa) z-buffer quantization error
(extra space to continue work)
Name: _____________________________  Student ID Number: _________________

(extra space to continue work)