PLEASE HAND IN

UNIVERSITY OF TORONTO
Faculty of Arts and Science

AUGUST 2020 EXAMINATIONS

CSC 418 H1F

Duration — 2 hours + 15 minutes to upload answers

No Aids Allowed

PLEASE HAND IN

Student Number: ____________

UTORid: ____________

Last (Family) Name(s): ____________

First (Given) Name(s): ____________

Do ***not*** *turn this page until you have received the signal to start.*
In the meantime, please read the instructions below *carefully*.

This final examination consists of 9 questions on 9 pages (including this one), printed on both sides of the paper. *When you receive the signal to start, please make sure that your copy of the examination is complete and fill in the identification section above.*

Answer each question on a separate sheet of paper or in any digital form you want (e.g. physical paper, iPad note taking app, etc.). Please *indicate clearly which question your work belongs to.* You will have 10 minutes (after the 50 minutes allotted for the exam) to organize and upload your answers to MarkUs. You can take photos of your answers on your phone, upload your answers as a PDF, PNGs, etc.

As a student, you help create a fair and inclusive writing environment. If you possess an unauthorized aid during an exam, you may be charged with an academic offence.

MARKING GUIDE

Nº 1:	______/ 6
Nº 2:	______/ 6
Nº 3:	______/ 6
Nº 4:	______/ 6
Nº 5:	______/ 6
Nº 6:	______/15
Nº 7:	______/15
Nº 8:	______/15
Nº 9:	______/ 5
TOTAL:	______/80

Question 1. Raster Images [6 MARKS]

Part (a) Bayer Filter [2 MARKS]

i– [1 MARK]

we use a linear interplotation-based demosaic method.

ii– [1 MARK]

where there are some big change in color.

Part (b) Image Manipulation [4 MARKS]

```
for (int i = 0; i < rgb.size(); i++) {
    rgb[i*3 + 1] = 20% · rgb[i*3 + 1];
    rgb[i*3 + 2] = 0;
}
```

Question 2. Ray Casting [6 MARKS]

Part (a) Planes [3 MARKS]

i– [1 MARK]

say the two points p_0, p_1 normal n

if $\vec{n} \cdot (p_0 - p_1) = 0$, it's on the plane, otherwise no.

0

ii– [2 MARKS]

$\vec{n} \cdot // u$

Part (b) Ray-Sphere Intersection [2 MARKS]

i– [1 MARK]

quadratic.

ii– [1 MARK]

say $ax^2 + bx + c = 0$.

$\sqrt{b^2 - 4ac} < 0$.

Part (c) Complexity [1 MARK]

i– [1 MARK]

O(mn)

Question 3. Ray Tracing [6 MARKS]

Part (a) Occlusions [3 MARKS]

i– [1 MARK]

compute the value of t of hitting that object.
if the resulted t is negative, ignore it.

ii– [2 MARKS]

compare the value of t, the smaller one take into account.

Part (b) Blinn-Phong [3 MARKS]

The specular term of Blinn-Phong shading is below, with the specular exponent α:

$$\underbrace{\mathbf{k}_s}_{\text{specular color}} * \underbrace{\mathbf{I}_s}_{\text{light color}} \max((\hat{\mathbf{h}} \cdot \hat{\mathbf{n}}), 0)^{\alpha} \tag{1}$$

i– [1 MARK]

$$\frac{e-p+l-p}{\|e-p+l-p\|}$$

ii– [2 MARKS]

the material will look less glossy to reflect light

Question 4. Bounding Volume Hierarchies [6 MARKS]

Part (a) Bounding Volumes [4 MARKS]

We covered 4 types of bounding volumes: sphere, AABB, OOBB, and convex hull.

i– [2 MARKS]

OOBB: because its oriented, it has direction.

ii– [2 MARKS]

convex hull: the total space used is the least.
so spent least time.

Part (b) AABBs [2 MARKS]

Consider a set of n objects in space.

i– [1 MARK]

O(n)

, **ii–** [1 mark] $O(n)$

Question 5. Meshes [6 marks]

Part (a) Normals [3 marks]

i– [1 mark]

It's a common way, we can use other method.

ii– [2 marks] Match each method to its best suited example.

per-face normals ○ ○ a cube
per-vertex normals ○ ○ a cylinder
per-corner normals ○ ○ a sphere

Part (b) Subdivision [3 marks]

Consider a *polygonal* mesh with v vertices, e edges and f faces.

i– [2 marks] True or false? Prove if true, or provide counter example if false.

False.

ii– [1 mark]

$4^k \cdot f$

Question 6. Shader Pipeline [15 marks]

Part (a) Projection [2 marks]

i– [1 mark]

for example, for art purpose.

ii– [1 mark] A model matrix transforms object space into world space.

Part (b) Bump and Displacement Mapping [4 marks]

i– [1 mark]

ii– [1 mark]

iii– [2 MARKS]

$$\tilde{\mathbf{n}} = \frac{\partial p}{\partial T} \times \frac{\partial p}{\partial B}.$$

Part (c) Perlin Noise [3 MARKS]

The Perlin noise algorithm starts by assigning random unit gradient vectors to the nodes of a grid. Say we have a 2D grid where grid points are at integer values.

i– [1 MARK]

$v = g \cdot (p - c)$

ii– [1 MARK]

iii– [1 MARK]

increase order of the chosen function used in smooth step.

Part (d) Shader [6 MARKS]

i– [1 MARK] Circle one.

mesh vertex positions camera transformation high-resolution color

ii– [1 MARK] Circle one.

a) vertex shader
b) tessellation control shader
c) tessellation eval shader
d) none (rasterization does shading automatically)
e) fragment shader

iii– [2 MARKS] Prove or counterexample.

counter example.

$$\left(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, 0\right) \times (1, 0, 0) = \left(0, 0, -\frac{\sqrt{2}}{2}\right)$$

$$\left\|\left(0, 0, -\frac{\sqrt{2}}{2}\right)\right\| \neq 1.$$

iv– [2 MARKS] Demonstrate how or give counterexample?

Question 7. Kinematics [15 MARKS]

Part (a) Linear Blend Skinning [3 MARKS]

i– [2 MARKS]

no. for a counter example. $K_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$K_2 = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ and $0.5 \cdot K_1 + 0.5 \cdot K_2$ results in a matrix $\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ which projects to z-axis.

ii– [1 MARK]

0

Part (b) Catmull-Rom Spline [3 MARKS]

Consider keyframes stored as parameter-timestamp pairs:

$$(\mathbf{p}_1, t_1 = 0.0), \quad (\mathbf{p}_2, t_2 = 1.0), \quad (\mathbf{p}_3, t_3 = 1.5), \quad (\mathbf{p}_4, t_4 = 2.25), \quad (\mathbf{p}_5, t_5 = 3)$$

i– [1 MARK]

P_1

ii– [2 MARKS]

$$\frac{P_4 - P_2}{\| P_4 - P_2 \|}$$

Part (c) Inverse Kinematics [8 MARKS]

i– [1 MARK]

$E(x) =$

ii– [7 MARKS]

```
a ← initial joint angles
E_cur = E( __X__(__a__) )
for outer = 1...100
   J = d__X(a)__/d__a__
   g = d__E(x)__/d__x__
   step_dir = - J * g
   lambda = lambda_max
   for inner = 1...10
     a_next = a + lambda * step_dir
     E_next = E( __X__(__a_next__) )
     if __E_curr__ < __E_next__
       lambda = __lambda/2__
     else
       break
   a = a_next
   __E_curr__ = E_next
```

Part (d) Line Search [1 MARK]

make sure that energy E decreased after gradient descent by thinking sa as a line and scale it from large to small. scaler.

Question 8. Mass-Spring Systems [15 MARKS]

Part (a) Sparse Matrices [5 MARKS]

i– . [1 MARK]

O(nk)

ii– [1 MARK]

O(n)

iii– [1 MARK] For every double precision floating point entry in a dense matrix, we need 8 bytes. For every entry in a sparse matrix we need 16 bytes.

iv– [1 MARK] For every integer entry in a dense matrix, we need 4 bytes. For every entry in a sparse matrix we need 12 bytes.

v– [1 MARK]

over 33.3%

Part (b) Physical simulation [9 MARKS]

i– . [2 MARKS]

$\mathbf{f} \in \mathbb{R}^{3}$

$m \in \mathbb{R}^{1}$

$\mathbf{a} \in \mathbb{R}^{3}$

ii– [1 MARK]

$V(\mathbf{x}_i, \mathbf{x}_j) = (\| x_i - x_j \| - r_{ij})^2 \cdot \frac{1}{2} k$

iii– [1 MARK]

$\mathbf{f}_{ij} = \sqrt{V \cdot 2k}$.

iv– [1 MARK]

when the length of spring equal to the rest length of spring.

v– [2 MARKS]

$$\mathbf{a}_t = \frac{x_{t+\Delta t} - 2x_t + x_{t-\Delta t}}{\Delta t^2}.$$

vi– [2 MARKS]

$\mathbf{f}_{\text{internal}} =$

Part (c) Time Integration [1 MARK]

i– [1 MARK]

Question 9. Computational Fabrication [5 MARKS]

Part (a) Manufacturing [5 MARKS]

i– [2 MARKS]

additive manufacturing. because objects are constructed by depositing material in layers.

ii– [2 MARKS]

subtractive manufactury. because objects are constructed by cutting away from a solid block of material.

iii– [1 MARK]

for additive manufactury,
The more complex the object is, the time and expense it spend are much less than subtractive methods.