Name ______________________________

GPU Programming
EE 4702-1
Final Examination

12 December 2013, 15:00–17:00 CST

Problem 1	________	(25 pts)
Problem 2	________	(25 pts)
Problem 3	________	(15 pts)
Problem 4	________	(10 pts)
Problem 5	________	(15 pts)
Problem 6	________	(10 pts)
Exam Total	________	(100 pts)

Alias ______________________________

Good Luck!

Problem 1: (25 pts) The code below computes forces between all pairs of a set of balls, similar to the code from the pre-final and Homework 3. Unlike those prior versions, the code below is written for the case where the number of balls (`chain_length`) is a multiple of the total number of threads.

Let c denote the number of balls, n denote the total number of threads (`num_threads`), and g denote the grid size (number of blocks). The size of a `float4` is 16 bytes. The code runs on an NVIDIA Kepler GPU, which supports requests of size 32, 64, and 128 bytes.

```
const int tid = threadIdx.x + blockIdx.x * blockDim.x;
const int num_threads = blockDim.x * gridDim.x;
const int a_idx_start = tid;
const int balls_per_thread = dc.chain_length / num_threads;
for ( int i=0; i<balls_per_thread; i++ )
  {
    const int a_idx = a_idx_start + i * num_threads;
    const float4 pos_a = dc.d_pos[a_idx];                  // Global Access A
    float3 force = make_float3(0,0,0);
    for ( int b_idx = 0;  b_idx < dc.chain_length;  b_idx++ )
      {
        const float4 pos_b = dc.d_pos[b_idx];              // Global Access B
        force += force_compute(pos_a,pos_b);
      }
    dc.d_vel[a_idx] += delta_t * dc.d_balls[a_idx].mass_inv * force;
  }
```

(*a*) In terms of n, c, and g compute the amount of data requested and used for the line marked Global Access A.

☐ Data requested by Global Access A. ☐ Data used by A.

(*b*) In terms of n, c, and g compute the amount of data requested and used for the line marked Global Access B.

☐ Data requested by Global Access B. ☐ Data used by B.

Problem 2: (25 pts) The code below is similar to the code from the previous problem except that shared memory is used to hold values needed for `pos_b`. The value of `csize` is not well chosen given the way the code is written. As before let c denote the number of balls, n denote the total number of threads, and g denote the grid size (number of blocks). The size of a `float4` is 16 bytes. The code runs on an NVIDIA Kepler GPU, which supports requests of size 32, 64, and 128 bytes.

```
int num_threads = blockDim.x * gridDim.x,  tid = threadIdx.x + blockIdx.x * blockDim.x,
int a_idx_start = tid,                     balls_per_thread = dc.chain_length / num_threads;
const int csize = 8;
__shared__ float4 c_pos[csize];
for ( int i=0; i<balls_per_thread; i++ ) {
    const int a_idx = a_idx_start + i * num_threads;
    const float4 pos_a = dc.d_pos[a_idx];                  // Global Access A
    float3 force = make_float3(0,0,0);
    for ( int b_idx = 0;  b_idx < dc.chain_length;  b_idx++ ) {
        const int c_idx = b_idx % csize;
        if ( c_idx == 0 ) {
            const int loc = threadIdx.x % csize;

            __syncthreads();

            c_pos[loc] = dc.d_pos[b_idx + loc];            // Global Access B

            __syncthreads();

          }
        const float4 pos_b = c_pos[c_idx];
        force += force_compute(pos_a,pos_b);
      }
    dc.d_vel[a_idx] += delta_t * dc.d_balls[a_idx].mass_inv * force;
  }
```

(a) In terms of n, c, and g compute the amount of data requested and used for the line marked Global Access B.

☐ Data requested by Global Access B. ☐ Data used by B.

(b) Choose `csize` to minimize memory access by Global Access B.

☐ Show new value of `csize`. ☐ Explain.

(c) Modify the code so that the amount of data accessed due to Global Access B matches the previous part when `csize` is set to the original value, 8. The change should be within the `if ( c_idx==0 )` block and it is only one line of code.

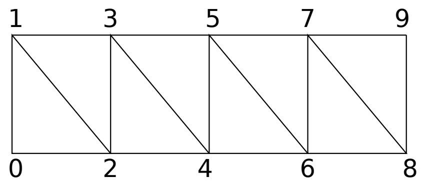
☐ Modify code to reduce waste when `csize=8`.

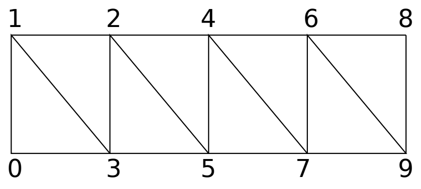
Problem 3: (15 pts) Answer the following questions about triangles.

(*a*) The diagrams below show two possible numberings for vertices for rendering a rectangle as a triangle strip.

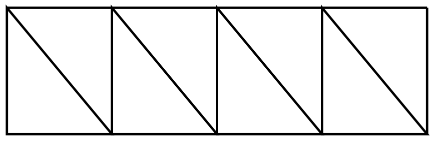
☐ Which one is correct?

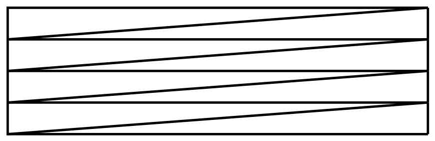
☐ Show how the triangles would be rendered for the incorrect case.





(*b*) Several possible strategies are being considered to render a rectangle.





Suppose the left figure above were rendered as a triangle strip (with the vertices correctly numbered).

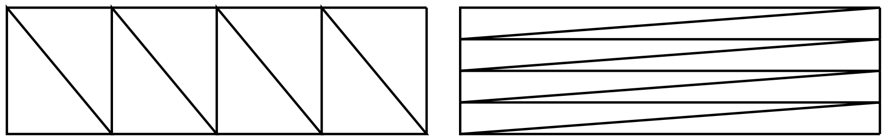
☐ How many times would the vertex shader be executed?

Suppose the left figure above was rendered as individual triangles.

☐ How many times would the vertex shader be executed?

Problem 3, continued:

(*c*) Consider the following two ways of tessellating a rectangle.



Suppose that lighting is computed in the vertex shader.

☐ Which tessellation above is better? ☐ Explain.

(*d*) Suppose that lighting were being computed in the fragment shader.

☐ Why would either tessellation above be wasteful?

Problem 4: (10 pts) In class we saw how we could obtain the mirror image of a vertex easily if the mirror were on the xz plane at $y = 0$. For such a mirror, the mirror image of a vertex at (x, y, z) would be at $(x, -y, z)$.

Appearing below are a vertex shader and geometry shader that do nothing special: The vertex shader computes the clip-space coordinates and lighting, and the geometry shader emits one triangle.

Modify the shader(s) so that for each original triangle two are emitted: one in the original position, and the other in the reflected position. (Don't worry about stenciling or anything like that.)

Hint: Don't forget that the mirror is in object-space (world-space) coordinates.

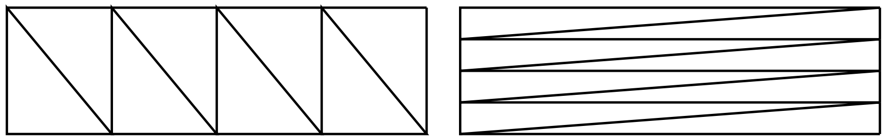
☐ Modify to emit reflected triangle, in addition to regular.

☐ Think about coordinate spaces.

```
#ifdef _VERTEX_SHADER_
void vs_main_basic() {
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;

  // Compute eye-space vertex coordinate and normal.
  // These are outputs of the vertex shader and inputs to the frag shader.
  vec4 var_vertex_e = gl_ModelViewMatrix * gl_Vertex;
  vec3 var_normal_e = normalize(gl_NormalMatrix * gl_Normal);
  vec4 lcolor = generic_lighting( var_vertex_e, gl_Color, var_normal_e);

  gl_BackColor = gl_FrontColor = lcolor;
}

out Data  {
  int hidx;  // Not used.
};
#endif

#ifdef _GEOMETRY_SHADER_
in Data {
  int hidx;  // Not used.
} In[3];

void gs_main_helix() {
  // Pre-defined input: gl_PositionIn[] (array of vec4, size determined by prim)
  // Pre-defined output: gl_Position (a vec4, read when EmitVertex called).
  for ( int i=0; i<3; i++ )
    {
      gl_FrontColor = gl_FrontColorIn[i];
      gl_BackColor = gl_BackColorIn[i];
      gl_Position = gl_PositionIn[i];
      EmitVertex();
    }
  EndPrimitive();
}
#endif
```

Problem 5: (15 pts) Answer each question below.

(*a*) Suppose we have a buffer object for vertices corresponding to the object on the lower left.



☐ How can we use that buffer object to render an object that will look like the one on the right?

(*b*) Describe a situation in which using `glVertex` rather than vertex arrays (`glDraw`) is a good idea.

☐ Situation in which `glVertex` better:

(*c*) Describe a situation in which using vertex arrays but without buffer objects is a good idea.

☐ Situation in which vertex arrays without buffer objects better:

Problem 6: (10 pts) In class the topic of texture filtering was introduced with a description of what would happen if a texture image of a picket fence (white stripes in front of a green background) where rendered without an appropriate MIPMAP level and without filtering. Either the fence or the grass would disappear.

(*a*) Illustrate the problem. On your diagram show the fence, some pixels and some texels. It is important to choose the size of the pixels and texels correctly.

☐ Illustration of problem. ☐ Show pixels. ☐ Show texels.

(*b*) Re-draw the diagram showing how the choice of an appropriate MIPMAP level can avoid the problem of the fence disappearing.

☐ Illustration of how MIPMAP level avoids problem.

(*c*) Draw a diagram showing an example of how linear filtering can improve the appearance of the fence.

☐ Example of how linear filtering improves appearance.