Exercises for Alex Benton's lectures

All work must be submitted by email no less than 48 hours before supervision.

1. **Voronoi Diagrams**
   a. What is *equiangularity*?
   b. What is the *empty circle property*?

2. **Implicit Surfaces**
   a. Explain the special cases in the polygonalization of an octree, and how you might address them.
   b. Summarize the *marching cubes* algorithm.

3. **Ray / Cone**
   a. Show how to find the first intersection between a ray and a finite-length, open-ended section of a right circular cone, apex at the origin, aligned along the x-axis, for which both ends of the finite length are on the positive x-axis ($0 \leqq x_{min} < x_{max}$).
   b. Extend this to cope with a closed cone (i.e. the same cone section, but truncated to a frustum with end caps). Take care to consider any special cases.
   c. Extend this further to give the normal vector at the intersection point.

4. **Path tracing** - A perfectly reflective mirrored sphere, S, is centered at the origin (0, 0, 0). Directly above it is a bright red 2 × 2 × 2 cube, C, centred at (0, 5, 0) and axis-aligned. The default background color of the scene is blue. A ray-tracing ray R is fired from (0, 1, 10) with direction (0, 0, −1). The scene is lit by an ambient light source and there are no other objects in the scene. What is the maximum radius of S such that the color calculated for R is red?

5. **Constructive Solid Geometry**
   a. List three ways of combining objects using constructive solid geometry (CSG), and describe how an object built using CSG can be represented using a binary tree.
   b. Given the intersection points of a ray with each primitive in the tree, explain how these points are passed up the tree by each type

of combination node to produce a list of intersection points for the whole CSG object.

c. Show how the Lego™ brick below can be constructed using Constructive Solid Geometry (CSG). You may assume the following primitives: sphere, cylinder, cone, torus, box. [You are expected to describe which primitives are needed and how they are combined but you are not expected to specify accurately all of the parameters of the primitives.]