Subdivision Surfaces and Simulating Physics

1. Implementing Subdivision Surfaces
   The half-edge data structure is designed to be efficient for the neighborhood queries required by subdivision. It stores a vertex array, face array, and half-edge array holding objects of the types shown in the C style declarations below.

   ```c
   struct HE_edge{
       HE_vert* end; // vertex at the end of the half-edge
       HE_edge* opposite; // oppositely oriented adjacent half-edge
       HE_face* leftFace; // face the half-edge borders
       HE_edge* next; // next half-edge around the face
   };
   struct HE_vert{
       float x, y, z;
       HE_edge* edge; // one of the half-edges emanating from the vertex
   };
   struct HE_face{
       HE_edge* edge; // one of the half-edges bordering the face
   };
   ```

   In the average case, how many operations are required to find all the neighbors of a given vertex using a half-edge data structure? How does that compare to using an indexed face set data structure? Assume each vertex has valence 6.

   \( O(1) \) on average since average valence 6 is a constant.

   \( O(F) \) where \( F \) is number of triangles in a mesh for an indexed face set.

   How would you implement a function

   ```c
   HE_vert * start(HE_edge * e) { return e->opp->end; }
   ```
2. Physics Engine

A particle begins at

\[
\begin{bmatrix}
1 \\
2 \\
3
\end{bmatrix}
\]

and is moving with velocity

\[
\begin{bmatrix}
1 \\
-1 \\
2
\end{bmatrix}
\]

per second, and acceleration

\[
\begin{bmatrix}
0 \\
1 \\
-1
\end{bmatrix}
\]

per second per second.

a. Use the second integral of the acceleration to compute the position after 5 seconds. The update equation you should use is:

\[
p' = p + \dot{p}t + \ddot{p} \frac{t^2}{2}
\]

[6, 9.5, 0.5]

b. Calculate the position using 5 time steps of 1 second each using the update equations below.

\[
p' = p + \dot{p}t \quad \ddot{p}' = \dot{p} + \ddot{p}t
\]

[6, 7, 3]

c. What is the error? Explain why it happens.

Error from assuming constant velocity over each timestep