Part 1

1. **Cube transformation**

   a.

$$M=T(1,1,2) \cdot R_z(45°) \cdot R_y(54.74°) \cdot R_z(-60°) \cdot R_y(-54.74°) \cdot R_z(-45°) \cdot T(-1,-1,-2)$$

Entries:

$$T(1,1,2) = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, T(-1,-1,-2) = \begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_z(45°) = \begin{bmatrix} \cos 45° & -\sin 45° & 0 & 0 \\ \sin 45° & \cos 45° & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$R_z(-45°) = \begin{bmatrix} \cos(-45°) & -\sin(-45°) & 0 & 0 \\ \sin(-45°) & \cos(-45°) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_y(54.74°) = \begin{bmatrix} \cos 54.74° & 0 & \sin 54.74° & 0 \\ 0 & 1 & 0 & 0 \\ -\sin 54.74° & 0 & \cos 54.74° & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

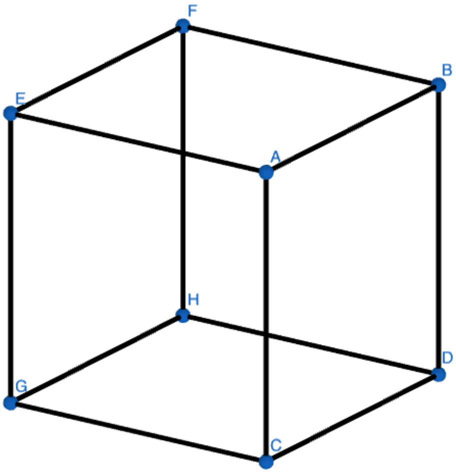
$$R_y(-54.74°) = \begin{bmatrix} \cos(-54.74°) & 0 & \sin(-54.74°) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(-54.74°) & 0 & \cos(-54.74°) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_z(-60°) = \begin{bmatrix} \cos(-60°) & -\sin(-60°) & 0 & 0 \\ \sin(-60°) & \cos(-60°) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Part 2

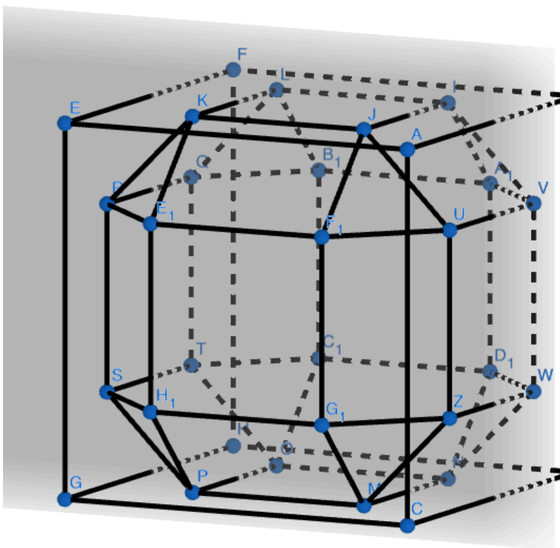
2. **First round subdivision**

Variables: v is the array of the vertices of the original cube, it has 6 elements, v1 is the array of the vertices of the cube after first round subdivision, it has 24 elements. F is array of faces of the original cube, represented using ordinal number of vertices, for example, a to h correspond to 1 to 8 in the picture, {1,0,4,5} means surface BAEF.



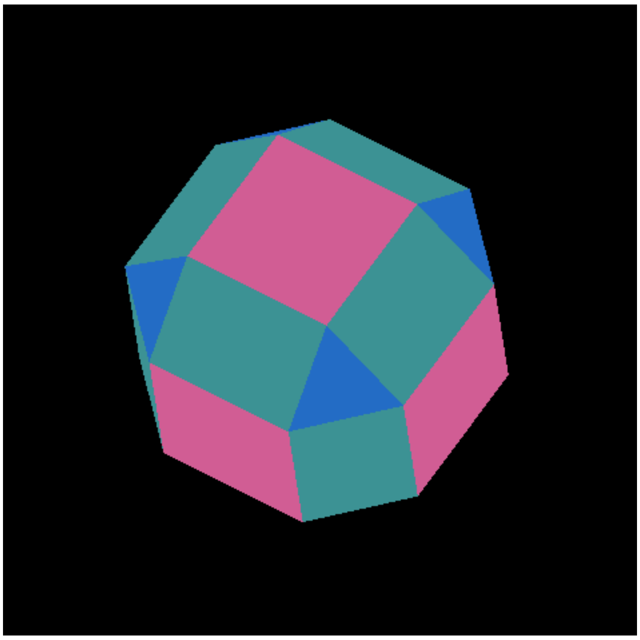
Functions:

Doosabin1() is the process of obtaining vertices of the subdivision results and store them in v1. For all 4 vertices of all 6 faces, it calculates x, y and z axis value according to the weights. For example, surface AEGC, it starts from A, F1’s value is weighted sum of AEGC, where



A:E:G:C=9:3:1:3, then it goes to the next point in this surface, E and calculates E1 using the same method.

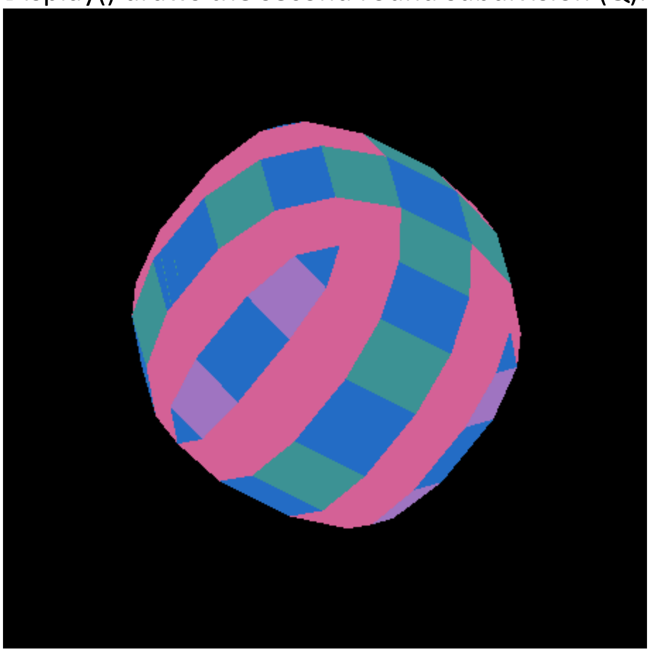
Display() draws the first round subdivision (Q) in the order of F-faces, E-faces and V-faces. The result is shown below.



3. Second round subdivision

Variables: same as the first round, in the second-round subdivision (R), v1 is vertices of Q and v2 is vertices of R. ff, ef and vf are f-faces, e-faces and v-faces of Q, the representation method is same as that in the previous question.

Functions:
Doosabin2() is the process of obtaining vertices of the subdivision results and store them in v2, there are three nested for loops, the first is to calculate vertices of f-faces, the second is for e-faces and the third is for v-faces. The results are stored in order in v2.
Display() draws the second round subdivision (Q). First it draws all face vertices (the blue



squares in the picture), then the four green strips (but the faces vertices are still blue), then the pink strips and finally the eight purple squares.

4. **Windmill**

Display() function draws the objects in order. First it draws the sphere at the origin, then the matrix translates by (0,-1,0) and rotate 90 degree clockwise around x axis, drawCylinder() draws the cylinder below with height 1.0f and the matrix goes back to the original point. Then it draws the three blades, the first blade is scaled to height:7 * width:1, and its orientation is upward, the second and third blade are scaled to the same size but rotated 120 degrees and 240 degrees counter-clockwise around the z axis.

glutIdleFunc() is called after glutDisplayFunc(), this means the display function is called when the application is idle. This causes the GLUT to always call the display function to produce the animation. Each call of display adds 1.2 to the variable angle, which is the rotation angle of the blades per unit time.