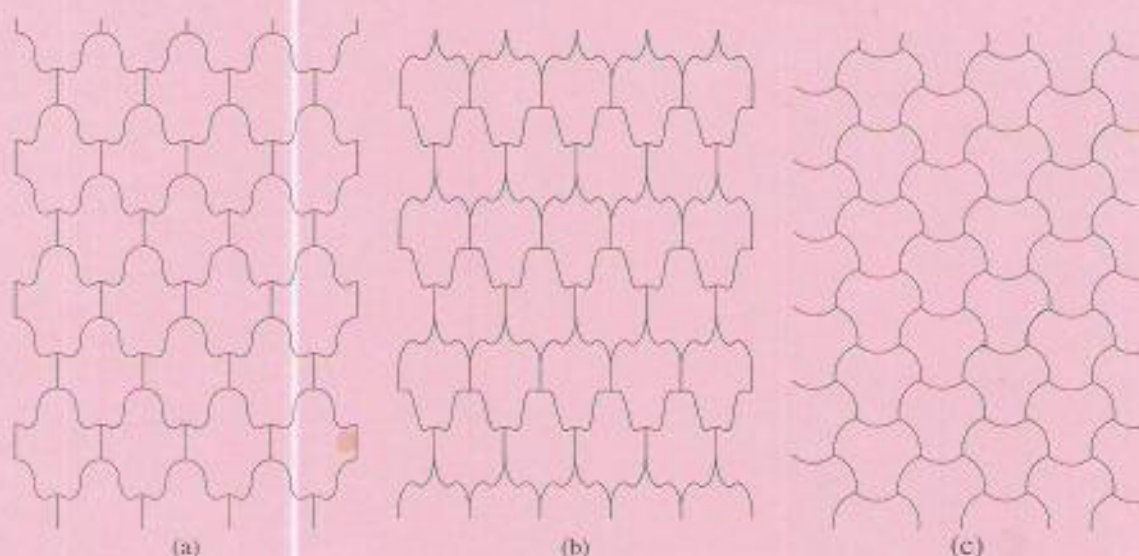


### Question 13

Carry out the algorithm described in the audio tape for *Unit GE4* to determine the wallpaper type of each of the tilings below, considered as wallpaper patterns. (They are IH14, IH15 and IH18, respectively, according to the classification of Grünbaum and Shephard.)

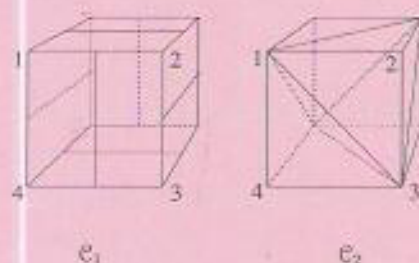
You should show, at each stage of the algorithm, which question you ask and what the answer is.

[15]



### Question 14

The cubes  $\mathcal{C}_1$  and  $\mathcal{C}_2$  below each have lines drawn on them bisecting each face. In each case the main diagonals are labelled 1, 2, 3, 4, as in VC4A; in the diagrams the labels appear on the corresponding vertices of the front face.



Let  $G_1$  be the group of symmetries of  $\mathcal{C}_1$  and  $G_2$  be the group of symmetries of  $\mathcal{C}_2$ .

- Given that  $\mathcal{C}_1$  and  $\mathcal{C}_2$  have the same *direct* symmetry group,  $G^+$ , describe its non-identity elements as rotations through specified angles about specified axes. [4]
- Describe the elements of  $G^+$  in terms of their cycle structure when they are represented as permutations on the symbols 1, 2, 3 and 4. To which of the 'standard' groups (i.e. cyclic, dihedral,  $A_n$ ,  $S_n$  or a direct product of two such) is  $G^+$  isomorphic? [4]
- To which of the standard groups are  $G_1$  and  $G_2$  isomorphic? Give reasons for your answers. [7]