COMPUTER SEARCH FOR NON-ISOMORPHIC CONVEX POLYHEDRA

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13. ABSTRACT

To classify the polyhedra, to survey the polyhedral shapes, and to exhaust their variety by orderly enumeration is a naturally attractive problem, noticed by Euler and Jakob Steiner, to which some mathematicians, especially Max Bruckner, devoted considerable work. With the latest high-speed digital computers decades of manual labor can be compressed into hours. This dissertation is concerned with the solution of the enumeration problem on a digital computer.

A tri- linear polyhedron is one in which each vertex is incident with exactly three edges. Two polyhedra are <u>isomorphic</u> if a one-to-one correspondence can be established between the vertices, edges, and faces of one with those of the other, so that the incidence relations between elements are preserved. Two polyhedra are called <u>equi-surrounded</u> if a one-to-one correspondence can be established between the faces of one and the faces of the other so that each pair of corresponding faces has equivalent surroundings -- i.e. the neighbors of the two faces in question, when taken in cyclic order clockwise, display the same pattern of edge-counts. Isomorphism implies equisurroundedness. A counter-example with 18 faces disproves the converse. However, for polyhedra with up to 17 faces we can apparently equate isomorphism with equisurroundedness.

A polyhedron of F faces can be made from a polyhedron of F-1 faces by <u>partitioning</u> one face into two. Intuitively, this is done by drawing a line segment across a face, creasing the face along the partition line, and popping it outward to retain convexity. If the partition line does not pass through an existing vertex, and the (F-1)-hedron is tri-linear, then the F-hedron created (cont.....)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure Page

CHAPTER I

INTRODUCTION AND HISTORICAL REMARKS

Source of the Question.

Serious mathematicians as well as laymen from as far back as Plato and Archimedes have concerned themselves with the study of polyhedra. It is generally believed that the regular polyhedra (those whose faces are regular congruent polygons and whose solid angles are congruent) of four, six, and eight faces were known to the Egyptians, but it remained for the Pythagoreans of about 500 B.C. to discover the other two -- those with twelve and twenty faces. Plato, in his metaphysical approach to things, associated the tetrahedron with fire, the cube with earth, the octahedron with air, the dodecahedron with the universe (possibly because it was discovered last), and the icosahedron with water.

On a more scientific basis, we find references in Euler's work, [22] page 90, that indicate clearly that Euler thought about and posed, though loosely, the general question with which we are here concerned.

> Genera notabiliora, ad quae omnia solida figuris planis inclusa sunt referenda, enumerare nominibusque idoneis denotare.

or,

> Enumerate the more important kinds of polyhedra and give them appropriate names.

In response to this self-posed question he then lists certain polyhedra of up to sixteen faces and makes comments about them. In particular, [22] page 93, states:

> The fourth genus has only one species, which is the triangular prism. The subsequent genera usually have several species, but we cannot go into their enumeration because, for the time being, the other properties of the polyhedra here involved are not sufficiently well known.

This indicates that Euler wondered about the general problem of enumeration of polyhedra but, at that time, was unable to come to any general conclusions.

The nineteenth century mathematician, Jakob Steiner, compactly posed the question, [23] page 227.

> Le nombre des faces d'un polyèdre étant donné, on peut demander, de quelle nature peuvent être ces faces. Quelle est la loi générale?

Other mathematicians who spent considerable time studying polyhedra were The Reverend Thomas P. Kirkman, and Professors Oswald Hermes and Max Brückner. Hermes and Brückner, in particular spent decades enumerating polyhedra by hand. Some of their results are discussed in Chapter II.

In mentioning polyhedra, both Euler and Steiner meant convex polyhedra. The aim of this dissertation is the enumeration of convex polyhedra subject to a restriction which will be stated below (tri-linear convex polyhedra), using a digital computer.

Representation of Polyhedra.

Aside from three-dimensional models, there are many useful ways to represent polyhedra. Some of those which we will have occasion to use later are the following:

1. Straight line nets in a plane, drawn by imagining one face to be expanded until all the other lines of the polyhedron, when projected onto the plane of this face, fall into its interior. For example, the triangular prism represented in this way is shown in Fig. 1.

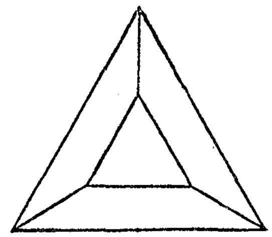


Fig. 1.

2. Curvilinear nets in a plane, topologically equivalent to the straight line nets. For example, the cube is shown in Fig. 2; the diagram contains two concentric circles.

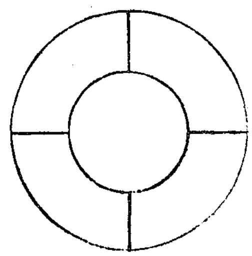


Fig. 2.

3. Curvilinear nets on a sphere, which permit visualization of polyhedra of many faces for which it is difficult to construct an ordinary three-dimensional model.

4. A list of the neighboring faces of each face, in cyclic order,

   a. by name. For example, if the faces of the triangular prism are labelled as shown in Fig. 3, the representation of the polyhedron becomes the following set of "words," one for each face:

      234
      1453
      1254
      1352
      243

   It is understood that these five consecutive "words" correspond to the faces labeled 1, 2, 3, 4, and 5, respectively.

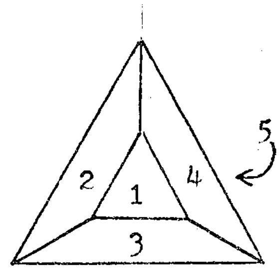


Fig. 3.

b. by edge-count. For example, the same triangular prism would be represented by the following set of words, one for each face, showing the number of edges possessed by each of that face's neighbors, in cyclic order, but without regard to the names of the faces:

444
3434
3434
3434
444

5. Abstract definition. A polyhedron is a system containing three kinds of elements named as follows:

a. "0-dimensional element" or "vertex,"

b. "1-dimensional element" or "edge,"

c. "2-dimensional element" or "face."

There is a relation between unlike elements which we call "incidence"; this relation is symmetric -- if x is incident with y then y is incident with x. The system satisfies the following axioms:

(0) If an edge is incident with both a face and a vertex, then the face is incident with the vertex.

(1) Each edge is incident with two and only two

(a) vertices.

(b) faces.

(2) There can be no more than one edge incident with both of any two given

   (a) vertices.

   (b) faces.

(3a) Each vertex is incident with at least three edges.

(3b) Each face is incident with at least three edges.

(4) If each of two faces is incident with each of two vertices, there is an edge incident with both faces and both vertices.

Comments:

On (1) and (2). Two faces (vertices) incident with the same edge are called neighbors, and are said to be contiguous, or adjoining to each other.

On (3a). If this axiom is changed to read "exactly three edges," then a special class of polyhedra is defined, called tri-linear polyhedra.

On (4). This axiom is not valid for non-convex polyhedra.

On the whole list of axioms (0), (1a), (1b), (2a), (2b), (3a), (3b), (4). This list does not yield a complete characterization of the concept of polyhedron that we have in view. "Topological" conditions must be added: the system must be connected, simply connected, and orientable, and each face must be simply connected (the neighboring faces must form a single cycle). We omit the axiomatic formulation of these topological conditions -- they are less prominent in our work and we have nothing important to add to Steinitz' work [4,5] in this respect. Yet these topological conditions are essential. They rule out such systems of faces, edges, and vertices as we may find in a pair of disconnected polyhedra, or in a torus-shaped polyhedron, or in a polyhedral Klein bottle, or in a polyhedron with some ring-shaped faces, etc.

Isomorphism.

Polyhedron A is said to be isomorphic with polyhedron B if a one-to-one correspondence can be established between:

a. the vertices of A and the vertices of B,

b. the edges of A and the edges of B, and

c. the faces of A and the faces of B,

such that the incidence relations between elements are preserved. Even if polyhedron A is turned "inside out" in the process of mapping it on polyhedron B, (that is, if the cyclic order of the faces surrounding each face is reversed), A and B are still considered to be isomorphic. In particular, affine mappings with negative determinant are permissible. Since the representation of a polyhedron described in 4a of the preceding section (exhibiting the neighbors by name) lists each face of the polyhedron and shows the identity of each of its neighbors in cyclic order, each edge is completely identified by the two faces which join to form it, and each vertex is identified by a face and two successive neighbors of that face. Hence it is obvious that two polyhedra are isomorphic if and only if their faces can be so labelled (by a permutation of the given labels) that their representations in the manner of 4a are identical.

Equisurrounded.

Two polyhedra whose representations in the manner of paragraph 4b above are identical will be called equisurrounded. We shall see in Chapter IV that equisurroundedness is a necessary but not sufficient condition for isomorphism.

General Theory.

Leonhard Euler (1707-1783) was born in Basel. He was a student of Johann Bernoulli and an associate of Bernoulli's two sons, Daniel and Nicholas. He was a prolific writer and made significant contributions to almost every field of mathematics. He is called the founder of the morphology of polyhedra, having discovered the famous fundamental law for convex polyhedra:

$$V - E + F = 2$$

where V, E, and F, are the numbers of vertices, edges, and faces of the polyhedron. Polyhedra which are not topological spheres always have a value different from 2 on the right side of Euler's equation above, but whatever that value might be, it is called the Euler characteristic. The Euler characteristic of a polyhedron is intimately connected with the topological nature of the polyhedron. For instance, a polyhedron which is a topological torus has Euler characteristic equal to zero. (Imagine cutting the torus at one place and closing the ends. If this figure is then straightened out into a cylindrical shape it becomes a convex polyhedron, with Euler characteristic equal to 2. If the cut was made along existing edges of the original polyhedron, then the cylinder has the same difference, vertices minus edges, but two more faces than the original polyhedron.)

One of the several proofs of Euler's theorem is as follows: Consider the straight line projection of the polyhedron on a plane (representation 1). Ignoring the base face, if we can show that the remaining figure satisfies:

$$V - E + F = 1$$

then, adding the base face we obtain Euler's formula. We proceed by subdividing each face into triangles, by drawing diagonals. For each diagonal added, E and F are increased by one, and V remains the same, so the characteristic $V - E + F$ is unchanged. Finally the figure consists of a set of triangles, some of which are on the outside boundary of the figure and some of which are interior. Of those on the boundary, some have two outside edges and some have only one, where "outside edge" means an edge belonging to no other triangle. Choose any boundary triangle and erase its outside edges. If it has only one, the resulting figure has the same V, but both E and F are reduced by one, hence the characteristic is unchanged. If, on the other hand, the triangle has two outside edges, then we also erase the vertex at their intersection. The result reduces V and F by 1, and E by 2, leaving the characteristic unchanged.

Since there is only a finite number of triangles to start with, we are assured of reaching a state wherein the figure contains only one triangle, which obviously has:

$$V = 3, \quad E = 3, \quad F = 1, \quad \text{with } V-E+F = 1.$$

We conclude that the figure with which we began had characteristic equal to 1, so adding the base face we have Euler's theorem:

$$V - E + F = 2.$$

There are other proofs[1], some of which involve very different ideas. The above proof was not flawlessly presented. Without a more careful elaboration of details, the method could admit an imprudent choice of edges to be erased, by which the figure could be divided into two disconnected nets, each of which has characteristic equal to 1, or lead to other difficulties.

Steinitz' Theorem.

In a polyhedron satisfying axiom (4) every pair of vertices, P and Q, which are each incident with both of two faces, α and β, are joined by an edge PQ which is incident with both α and β. We call such a polyhedron regularly connected, paraphrasing a term introduced by Steinitz, who defines a K-polyhedron as a regularly connected polyhedron with Euler characteristic equal to 2. Steinitz' theorem states that every K-polyhedron is realizable as a convex polyhedron. See [5] pages 227-229. Steinitz' theorem is basically important to our work; it enables us to represent convex polyhedra on a digital computer.

Splitting.

A polyhedron having F+1 faces can be derived from one having F faces by splitting one face into two. There are three types of splits, or partitions of faces; see Fig. 4.

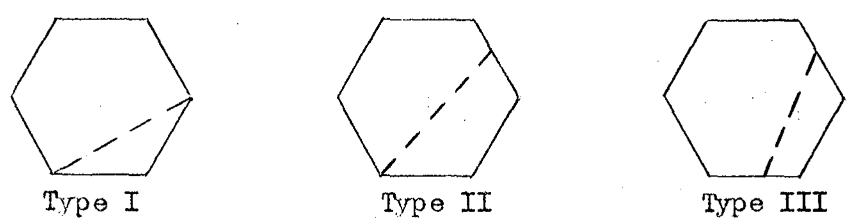


Fig. 4.

[1]See e.g. Polya [8] page 54, exercise 9.

These three types are distinguished by the number of vertices lying on the partition line. A split is accomplished by imagining the face to be scored or creased along the partition line, and pushed outward to form two faces while retaining the convexity of the figure. Steinitz [4] page 192, proved the following theorem.

Theorem 1. Any convex polyhedron of F faces can be derived by starting with the tetrahedron and making partitions of Type I, II, and III.

Diophantine Relations.

By axioms (1b), (2b), and (3b), each face has as many different neighbors as it has edges. No two of its edges can be incident with the same neighbor, hence the maximum number of edges for any face of an F-hedron is F-1. Designating as f_k the number of k-gon faces in a polyhedron, we can add up the faces and edges of the polyhedron and get the following relations:

$$f_3 + f_4 + \dots + f_{F-1} = F$$

$$3f_3 + 4f_4 + \dots + (F-1)f_{F-1} = 2E$$

We also have Euler's relation:

$$V - E + F = 2.$$

Since we are dealing with numbers of things, solutions $(f_3, f_4 \dots f_{F-1})$ of these equations must be in non-negative integers. In general, there are several solutions, looking at the system from a strictly algebraic point of view; however, not every solution of this diophantine system is realizable as a convex polyhedron. Each solution for which there is at least one convex polyhedron defines a Tribe, a non-empty set of convex polyhedra, containing, in general, several members. Regarding the f_k as successive digits, with f_3 in the units position, we obtain a tribe identification number to which we will refer repeatedly below. For clarification, a few examples are shown here:

polyhedron	tribe
tetrahedron	4
triangular prism	32
cube	60
hexagonal prism	2060

CHAPTER II

TRI-LINEAR POLYHEDRA

Definition.

A polyhedron having exclusively trihedral vertices will be called a tri-linear polyhedron. When there is no danger of confusion, just the word polyhedron will be used.

The theory of tri-linear polyhedra has a polar or dual counterpart in the theory of polyhedra having exclusively triangular faces. We will deal only with tri-linear polyhedra.

Euler's Theorem.

By Euler's theorem:

$$V - E + F = 2.$$

Then, since each vertex has three edges leading to it, and since each edge is shared by two vertices, we have, for tri-linear polyhedra:

$$3V = 2E.$$

Combining these relations we get:

$$E = 3(F-2)$$

$$V = 2(F-2).$$

The cube, for instance, is a tri-linear polyhedron with $F = 6$, $E = 12$, and $V = 8$.

Splitting.

Partitions of Types I and II produce non-trilinear polyhedra. Hence we must disallow all but Type III partitions in the creation of tri-linear polyhedra. Since a partition can never reduce the number of edges incident with a given vertex, it follows from Steinitz' theorem (Theorem 1) that any tri-linear polyhedron can be obtained from the tetrahedron by partitions of Type III. However, it is considerably easier to prove this consequence than to prove Steinitz' entire theorem, so we will give a new independent proof. First we must define the inverse process to splitting.

Merging.

We have been talking about creating polyhedra of F+1 faces from F-hedra by splitting faces. Consider the inverse process, which we will call merging. In the sketch, Fig. 5, consider merging faces #1 and #2 by erasing their common edge. The result will be labelled face #1.

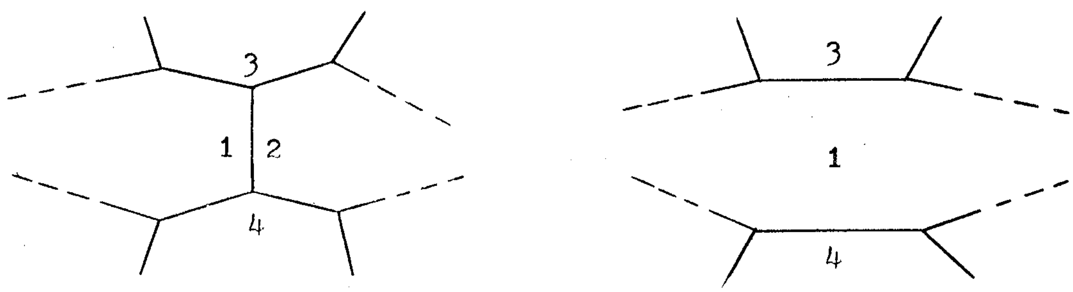


Fig. 5.

If we denote the edge count of face j before merging by e_j, and the same after merging by e'_j, we can make the following general remarks:

$$e'_1 = e_1 + e_2 - 4$$

$$e'_3 = e_3 - 1$$

$$e'_4 = e_4 - 1 \ .$$

Theorem 2. (Splitting Theorem) We can obtain any convex tri-linear polyhedron by starting with the tetrahedron and making face partitions of Type III (i.e., partitions in which the partition line does not pass through an existing vertex).

In order to prove the splitting theorem, we first need a lemma.

Lemma. If, in a tri-linear polyhedron, there are two triangles incident with the same edge, the polyhedron is, in fact, a tetrahedron.

Proof. Since each vertex of a tri-linear polyhedron is, by definition, a trihedral vertex, Fig. 6 represents the hypothesized pair of adjacent triangles. Vertices C and D are already trihedral, and vertices A and B need another line each.

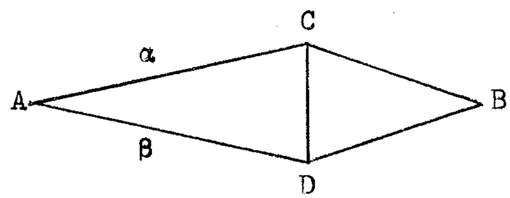


Fig. 6.

Now consider faces α and β, each of which is incident with both vertices A and B, by axiom (0) of the abstract definition of a polyhedron. Then by axiom (4) there must be an edge incident with both vertices, A and B, and both faces, α and β. Hence α and β must be triangular, which proves the lemma.

Proof of Theorem 2: Now, by induction, we can prove the main theorem on splitting. We know that there is only one four-faced polyhedron, the tetrahedron, which happens to be tri-linear. It is trivially derivable from itself, by splittings whose number is zero.

Using the method of mathematical induction, we assume that all tri-linear F-hedra can be made from the tetrahedron by splitting, and we must prove that the same is true for the (F+1)-hedra. For this purpose, we divide the (F+1)-hedra into two classes -- those having some triangular faces, and those having none.

Case I. Some triangles. By the lemma, triangles cannot be neighbors, and so we can find a triangular face with a non-triangular neighbor, and merge the two. Now we must check the axioms. Let us keep a sketch of the situation before us (Fig. 7). We plan to merge faces α and β.

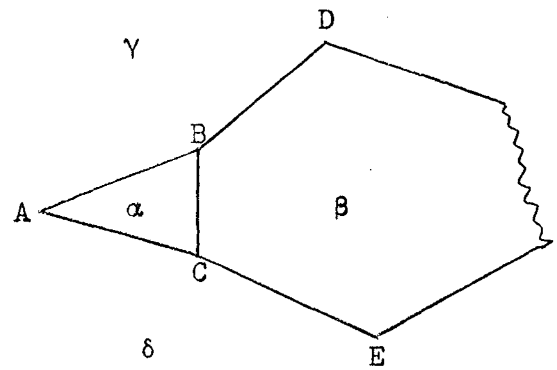


Fig. 7.

Axiom (0). Edges AB and BD become one edge AD after merging. No change in incidence relations of the remaining vertices (different from B and C) takes place. A similar argument holds for edge AE. There is no change in the incidence relations of the elements not emphasized by Fig. 7.

Axiom (1a). The vertex common to both of two merged edges, for instance edges AB and BD, is eliminated, leaving only two vertices incident with the merged edge, AD.

Axiom (1b). On one side of a merged edge, e.g. consisting of AB and BD, lies one face. On the other side lie two faces before merging, and one afterwards. Hence the merged edge, AD, is incident with only two faces.

Axiom (2a). The only way this axiom could be violated would be if a biangle would be created by the merger. This could occur if either β, γ, or δ were triangles. However, by the lemma, this is not possible.

Axiom (2b). To violate this axiom, one must merge two faces which belong to an arrangement we call a "belt" containing three faces. A "three-faced belt" is a set of three mutually contiguous faces which do not have a common vertex; see Fig. 8.

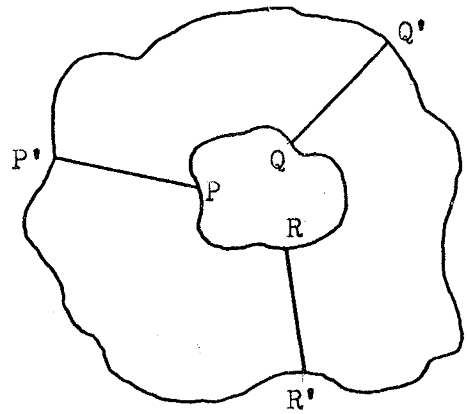


Fig. 8.

Each of the three faces participating in the belt has at least four vertices (P, P', Q and Q', for example); none of the three can be a triangle. And so, in the case of Fig. 7, the faces α and β cannot form a belt with any third face, since α is a triangle.

Axiom (3a). After the merger, vertices B and C in the example are eliminated, and none of the other vertices is changed with regard to its trihedral nature, as we have already mentioned above.

Axiom (3b). The only faces affected by the merger are α, β, γ, and δ. For a face to be incident with less than three edges, a biangle would have to be formed. This was ruled out while we examined axiom (2a).

Axiom (4). The edge required by this axiom is, in the one case, the composite edge ABD, and in the other, ACE. Faces γ and δ have a common edge emanating from vertex A, which is unaffected by the merger. They need not have, and indeed cannot have, any other, since face β cannot be a triangle (hence D and E are distinct vertices).

Case II. No Triangle. The only axioms which require special attention in this case are (2b) and (3b). All others are proved inviolate by the same arguments as in Case I. See Fig. 9.

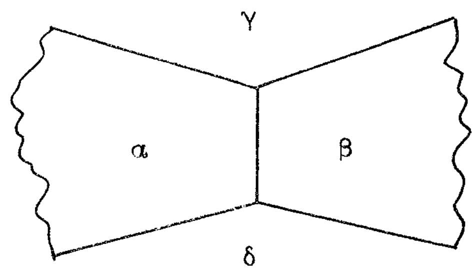


Fig. 9.

Axiom (3b). Each of the four faces affected by the merger has edge-count greater than three, hence after the merger γ and δ will have just one less than before and the merged face, αβ, will have $m + n - 4$, if α and β had m and n, respectively. No edge-count will be reduced to less than three, hence no biangles will be formed by the merger.

Axiom (2b). This axiom takes a little more discussion, so I left it to the last. First, note how merging can cause two faces to have more than one edge in common. It must be that the two merged faces, α and β, are both neighbors of a third face, ε, so that α, β, and ε form a belt around the polyhedron, as defined above. Erasing the line common to faces α and β would result in the new face, αβ, having two edges in common with the base face, ε.

Examples of three-faced belts are shown in Figs. 10 and 11, where erasing the edge common to faces α and β will violate axiom (2b). Note that in the decahedron of Fig. 11 there exist two belts, αβε and αδε .

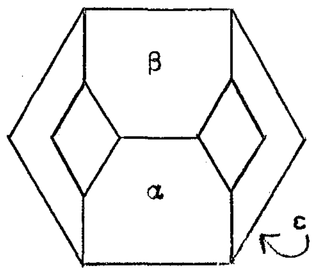


Fig. 10.

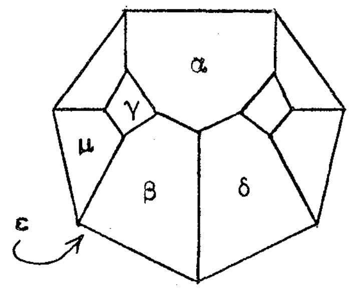


Fig. 11.

What we want to be able to say is that even in a polyhedron not free from belts we can find some edge to erase which will not result in a violation of axiom (2b).

Consider that a belt divides the remaining elements of a net into two parts -- call them the <u>inside</u> and the <u>outside</u> of the belt. If we disregard the outside, and examine just the belt and its inside, we can conclude that there must be at least three faces on the inside. For if there were only one, it would have to be a triangle, and this polyhedron contains no triangles. If there were two faces inside, then one would have to be a triangle (see Fig. 12). Hence there must be at least three faces inside.

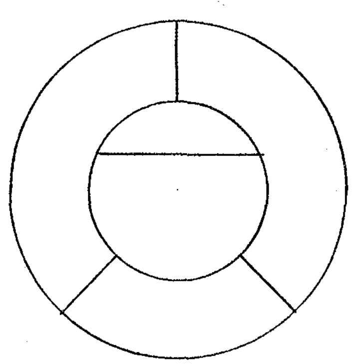


Fig. 12.

Next we should state the obvious fact that no face from the inside can form a belt with a face from the outside of a belt (our polyhedron is simply connected).

If we examine a belt and its inside, we may find that it contains other belts, and they could involve one or two members of the present belt. For ease of communication, let us call the belt we start with B, and such an alternate belt contained partly or totally inside B, B'. (For instance in Fig. 11, α, β, and ε can be considered to form the belt B, and α, δ, and ε to form B'.) Picking such a new belt, B', we can drop the faces which are outside it (there will be at least one to drop), and then proceed to examine B' and its inside. We note in passing that if belt B had b faces inside it, belt B' will have at most b-1 faces inside it. If we continue this process we can be assured of running out of belts ultimately, since we drop at least one face each time. The final belt will contain at least three faces inside it, as we have seen above, and so we can choose any two of them to merge, being sure that they do not form a belt with any one other face.

This completes the proof of the Splitting Theorem for tri-linear polyhedra.

Diophantine Relations for Tri-linear Polyhedra.

Theorem 3. Triangles, quadrilaterals, and pentagons cannot simultaneously be absent from a tri-linear polyhedron.

Proof: Consider the relations below, where f_j still represents the number of j-gon faces of a polyhedron:

(1) $$f_3 + f_4 + \dots + f_{F-1} = F$$

(2) $$3f_3 + 4f_4 + \dots + (F-1)f_{F-1} = 2E = 6(F-2) .$$

In equation (2), $2E = 6(F-2)$ because of Euler's relations for tri-linear polyhedra. Now if we multiply equation (1) by 6 and subtract equation (2) from it, we get:

$$(3) \quad 3f_3 + 2f_4 + f_5 - (f_7 + 2f_8 + \dots + (F-7)f_{F-1}) = 12$$

or, since the f_j are all non-negative, we arrive at the inequality:

$$(4) \qquad 3f_3 + 2f_4 + f_5 \geq 12$$

which says that triangles, quadrilaterals, and pentagons cannot simultaneously be absent. The case of equality is attained in (4) if there is no face with more than six sides. We may also observe that the well-known inequality (4) holds unrestrictedly for convex, not necessarily tri-linear, polyhedra, and so do some of the consequences we shall derive from it.

Now for the special case of F = 6, I should like to investigate the solution of the above diophantine equations, (1) and (2). If we multiply the first equation by 5 and subtract the second, for F = 6, we get:

$$2f_3 + f_4 = 6 \text{ .}$$

This equation, taken together with

$$f_3 + f_4 + f_5 = 6$$

yields $f_3 = f_5$, and so the system has exactly four solutions in non-negative integers.

f_5	f_4	f_3
3	0	3
2	2	2
1	4	1
0	6	0

Only two of these are realizable as convex tri-linear polyhedra, namely 222 and 060 (see Figs. 13 and 14 respectively).

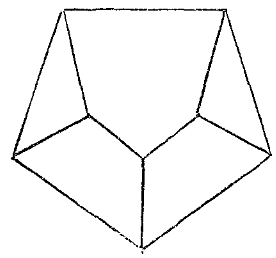


Fig. 13.

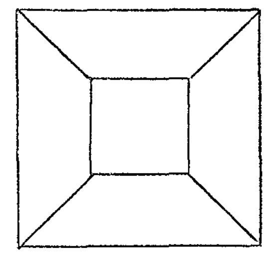


Fig. 14.

The others cannot be drawn in such a way as to satisfy the axioms. This will follow from Theorems 4 and 5 which will be stated here and proved later in this chapter in the section on Kirkman polyhedra.

Theorem 4. In a tri-linear F-hedron containing as base an (F-1)-gonal face, at least two of the remaining faces are triangular.

Theorem 5. In an F-hedron having an (F-1)-gonal face, where $F > 4$, there can be no more than $[\frac{1}{2}(F-1)]$ triangular faces (where $[X]$ denotes the greatest integer contained in X).

Each of the three solutions to the diophantine system, 303, 222, and 141, contains an (F-1)-gon base, where $F = 6$. Hence, invoking Theorems 4 and 5 we have:

$$2 \leq f_3 \leq 2 .$$

That is, since a pentagon is present, the number of triangles must be exactly two. This shows that the solutions 303 and 141 are not realizable as convex tri-linear polyhedra.

Faces with Limited Edge-Count.

It may be of interest to study polyhedra of a large number of faces, none of which has more than, say, M edges. Let us define as the maximum edge-count of a polyhedron the number of sides of the face with the most sides. It would be convenient if we could derive each polyhedron of the subclass for which the maximum edge-count does not exceed a given number M from the tetrahedron by successive splittings without using intermediate polyhedra outside the subclass. It turned out, however, rather surprisingly, that such a derivation is not always possible. The following theorems, 6 and 7, yield substantial information about the cases $M = 5$ and $M = 6$, respectively.

Theorem 6. In a tri-linear polyhedron with F faces and maximum edge-count ≤ 5 there are two adjacent faces which can be merged into one face with no more than 5 sides. This statement is true for $F \leq 11$, but false for $F = 12$.

Theorem 7. In a tri-linear polyhedron with F faces and maximum edge-count ≤ 6 there are two adjacent faces which can be merged into one face with no more than 6 sides. This statement is true for $F \leq 31$, but false for $F = 32$.

Let us recall a simple fact discussed above (in connection with Fig. 5). If two adjacent faces with m and n sides, respectively, are merged, the resulting face has $m + n - 4$ sides. Let us also recall the inequality (4) which goes over into the equation:

$$3f_3 + 2f_4 + f_5 = 12 \qquad (5)$$

when, as in the cases under consideration, the maximum edge-count does not exceed 6. And let us begin with two examples, the first concerned with the case $F = 12$ of Theorem 6, the second with the case $F = 32$ of Theorem 7.

First example. The regular dodecahedron has 12 pentagonal faces. If any two adjacent faces of it are merged, a polygon with $5 + 5 - 4$ faces, that is, a hexagon results. Therefore, the polygon with 11 faces from which our pentagonal dodecahedron is derived by one last splitting must have a hexagonal face. The dodecahedron is a polyhedron of the subclass with maximum edge-count ≤ 5 which we cannot derive from the tetrahedron by successive splittings without going outside this subclass.

Second example. The full page Fig. 15 shows one half of a polyhedron with 32 faces; the other half is identical and fits in with the one half shown by placing the protruding hexagons of one half adjacent to the outside pentagons of the other. (A metrically determined realization of this polyhedron is a "half-regular" or "Archimedean" solid, the "truncated icosahedron." Cut off each of the 12 vertices of a regular icosahedron so that a regular pentagonal face is created at each of the vertices, and a regular hexagon is made of each of the 20 originally triangular faces of the icosahedron.) Our 32-hedron has high symmetry: each pentagonal face is so situated in it as any other pentagonal face, and each hexagonal face as any other hexagonal face. The merger of two adjacent faces of our 32-hedron yields a polygon with

$$5 + 6 - 4$$

or

$$6 + 6 - 4$$

sides, a heptagon or an octagon. We have here a polyhedron with 32 faces of the subclass having maximum edge-count ≤ 6 which we cannot derive by splitting one face of a 31-hedron of the same subclass.

Our examples prove the "negative half" of Theorems 6 and 7. We start proving the positive half with a simple remark: merging a face of n sides with an adjacent quadrilateral or triangle cannot increase is ≤ 5 and $F \leq 11$. Any polyhedron of the subclass S with more than 4 faces can be derived from a polyhedron of the same subclass by splitting one face.

Theorem 9. A convex tri-linear polyhedron with F faces is said to belong to the subclass T if, and only if, its maximum edge-count is ≤ 6 and $F \leq 31$. Any polyhedron of the subclass T with more than 4 faces can be derived from a polyhedron of the same subclass by splitting one face.

Thus, each polyhedron of the subclass S can be connected with the tetrahedron by a chain of polyhedra belonging to the same subclass which are derived from each other by successive splittings (of Type III, of course) and the same holds for the subclass T.

One can prove Theorems 8 and 9 by combining the ideas of the proofs for Theorems 2, 6, and 7. I omit the details whose full presentation seems to be unavoidably long and fussy. Theorem 9 is essential to the appreciation of some of the work that will be presented in Chapter IV.

Kirkman Polyhedra. Dissection of a Polygon into Triangles.

We consider the so-called Kirkman polyhedra -- tri-linear polyhedra with at least one face of $F-1$ edges, where F is the number of faces in the polyhedron. In any Kirkman polyhedron, we choose a face of $F-1$ sides as the base; all other faces of the polyhedron are adjacent to the base. We draw a net of the polyhedron (representation 1), on the base. In this net, the vertices not incident with the base and the edges adjacent to, nor identical with, the base. I say that G is a <u>tree</u>, a connected graph containing no loop (no cycle).

Let e and v denote the number of edges and vertices belonging to G, respectively. Recalling that E and V are the number of edges and vertices in the entire polyhedron, we have:

$$\begin{aligned} e &= E - 2(F-1), \\ &= 3(F-2) - 2(F-1) \\ &= F-4. \end{aligned}$$

The number of vertices that do not belong to the base is:

$$\begin{aligned} v &= V - (F-1) \\ &= 2(F-2) - (F-1) \\ &= F-3. \end{aligned}$$

Thus:

$$v = e + 1.$$

It is well known that in a tree the number of vertices exceeds by one the number of edges. An inductive proof of this fact runs so: The simplest tree consists of a single node, has no edge, and so the fact asserted is obvious for a tree with only one node. Then, given that the relation is true for a tree of K nodes, adding another node cannot destroy the relation because the new node must be connected to just one of the existing nodes by just one edge (otherwise a loop would be formed). Thus the relation holds for the K+1 node tree.

Since G contains no loop, as we have observed above, G is the union of a certain number t of distinct trees, and so:

$$v = e + t.$$

Comparing with the above, we see that t = 1. Hence, G is a single tree; G is connected.

Let us digress for a moment and prove Theorems 4 and 5, stated above.

Theorem 4. In a tri-linear F-hedron containing as base an (F-1)-gonal face, at least two of the remaining faces are triangular.

Proof: We have seen that the graph, G, is a tree, a connected graph that contains no cycles. It is enough to consider $F > 4$. Then the tree has at least two extremities, X and Y. Since we are dealing exclusively with tri-linear polyhedra, X must be connected to two successive vertices in the base by two edges, forming a triangular face. Similarly, Y must form a triangular face with two vertices in the base face. Q.E.D.

Theorem 5. In an F-hedron having an (F-1)-gonal face, where $F > 4$, there can be no more than $[\frac{1}{2}(F-1)]$ triangular faces, where $[X]$ denotes the greatest integer contained in X.

Proof: By the lemma which says that the tetrahedron is the only tri-linear polyhedron containing adjacent triangles, the base (F-1)-gon can adjoin triangles only at every other edge, at most. Q.E.D.

Brückner characterized the Kirkman polyhedra as having no "Deckfläche" or crown faces. The "shape" of the tree G, i.e. the pattern of left turns and right turns one makes in traversing the tree, uniquely describes the polyhedron, since there is only one way to connect the tree to the base face. A vertex of G which is incident with only one edge belonging to the tree is connected to two adjacent vertices in the base face by two edges, thereby forming a triangular face. A vertex incident with two edges belonging to the tree is connected to a vertex in the base face by one edge, so placed that all the angles around the crown vertex are less than 180 degrees. A vertex incident with three edges belonging to the tree has no edges leading to the base face, since all vertices are trihedral.

Simply enclosing a tree in a circle is sufficient to permit drawing the entire net of its polyhedron. Take for instance the tree and corresponding polyhedron shown in Fig. 16.

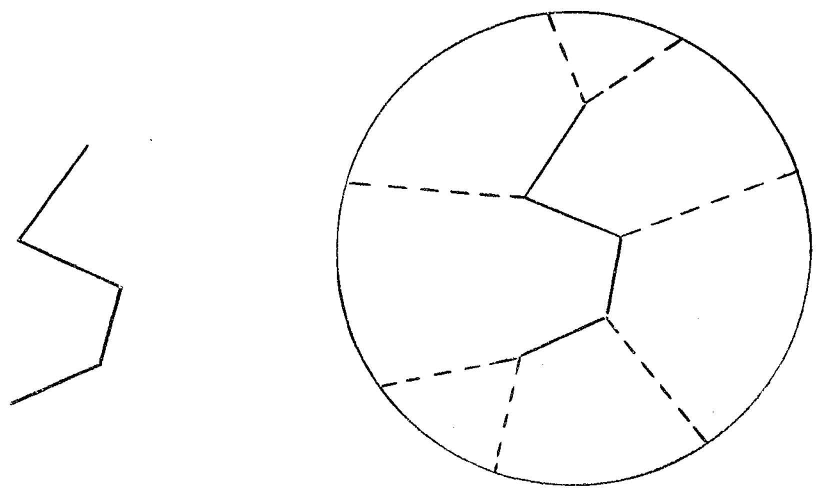


Fig. 16.

As we have seen above, there are $v = F-3$ vertices and $e = F-4$ edges in the tree G. Thus, there are five vertices and four edges in the tree of the octahedron of Fig. 16.

Note the combinatorial nature of the structure of a tree. Once a first edge is drawn, one has the choice of "turning left or right" at each succeeding vertex. Weeding out the isomorphisms and including vertices of order three in the tree complicate the enumeration of possible cases. Yet, as observed by Kirkman, the number of such non-isomorphic trees is exactly equal to the number of ways the base polygon can be dissected into triangles, assuming all the edges and angles of the base are equal and indistinguishable. More precisely, the Kirkman polyhedron problem is essentially the dual of the polygon dissection problem, in the sense that faces and vertices are interchanged. (For an exposition on duality, see [8] page 53, exercises 3 and 4, and their solutions.) In Fig. 17 for example, drawing the lines connecting the centroids of the triangles in the hexagon at left we get a tree which corresponds to the polyhedron shown at right.

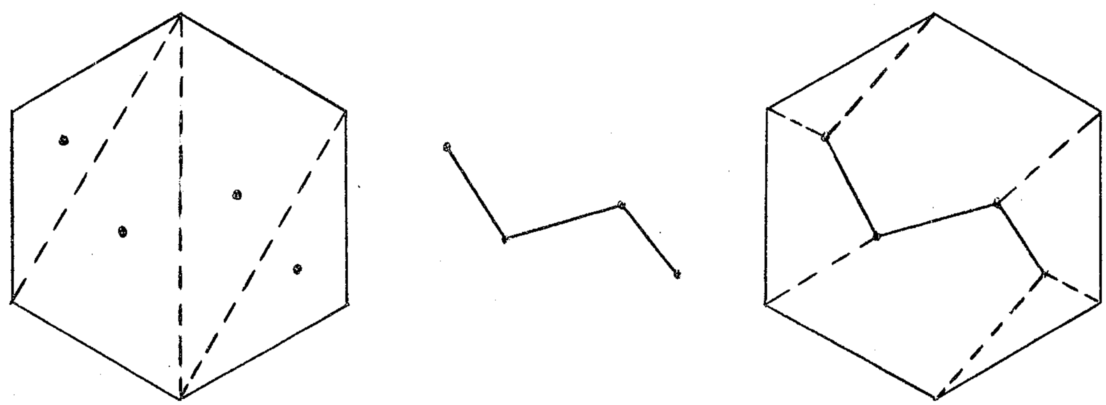


Fig. 17.

D_n, the total number of triangular dissections of an n-gon, admitting isomorphic dissections, was known to Euler. See [8] page 102, exercises 7, 8, and 9. Defining $D_2 = 1$, we have for $n \geq 3$,

$$D_n = D_2 D_{n-1} + D_3 D_{n-2} + \dots + D_{n-1} D_2$$
$$= \frac{2}{2}\,\frac{6}{4}\,\frac{10}{4}\,\frac{14}{5} \cdots \frac{4n-10}{n-1}$$
$$= \frac{(2n-4)!}{(n-2)!(n-1)!}$$
$$= \binom{2n-4}{n-2} \frac{1}{n-1} .$$

To show the connection between these numbers, D_n, and the number of (n+1)-hedra having an n-gon base, suppose the latter is called K(n+1) in honor of Kirkman. We will refer just to K when the number of faces, F = n+1, is understood. Each of the K types has a symmetry group of order S_i, i = 1, 2, 3, ... K. The base in itself admits a group of order 2n, the so-called dihedral group. Then, since edges of the base are considered indistinguishable, we have:

$$D_n = \frac{2n}{S_1} + \frac{2n}{S_2} + \dots + \frac{2n}{S_K}$$

or

$$\frac{D_n}{2n \sum_{i=1}^{K} \frac{1}{S_i}} = 1$$

or

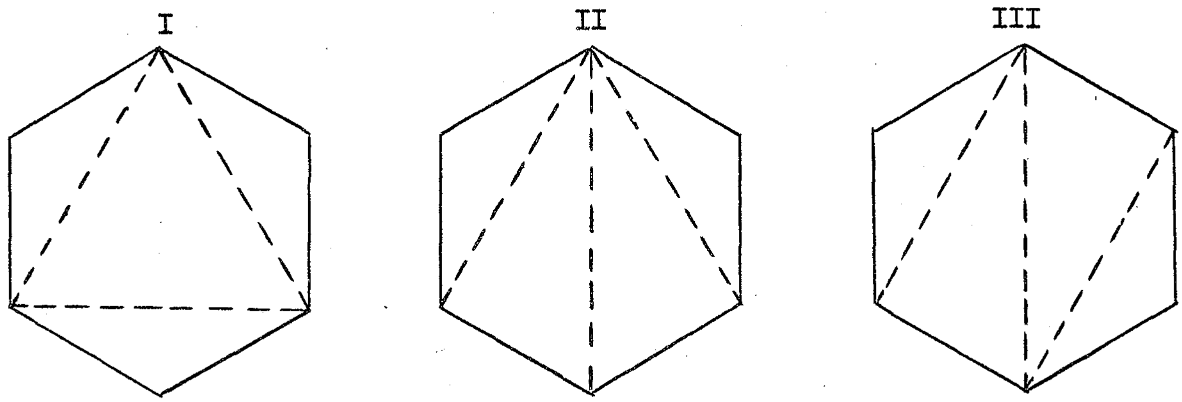
$$K = \frac{D_n}{2n} \cdot \left(\frac{K}{\sum_{i=1}^{K} \frac{1}{S_i}} \right) > \frac{D_n}{2n}$$

because the factor in parentheses, which is dropped to form the last inequality, is the harmonic mean of the S_i, all of which are ≥ 1, and not all of which are equal to 1.

Recalling that n = F-1, and defining L(n) as $D_n/2n$, we have the following table. The numbers for F $\geq$ 12 are Brückner's unverified results. Note that he certainly erred for F = 16, since his K(16) < L(16). See [2].

F	4	5	6	7	8	9	10	11	12	13	14	15	16
L	$\frac{1}{6}$	$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{6}$	3	$8\frac{1}{4}$	$23\frac{5}{6}$	$71\frac{1}{2}$	221	$699\frac{5}{6}$	2261	7429	$24763\frac{1}{3}$
K	1	1	1	3	4	12	27	82	228	731	2282	7531	24312

The foregoing discussion was more intuitive than exhaustive (for more details see [4] pages 50-55, [13], and [16]) so an example is particularly desirable. Consider F = 7, (n = 6). The three types of dissection for the hexagonal base and the operations which map these figures onto themselves are shown in Fig. 18.



I	II	III
I	I	I
M	M	R_{180}
R_{120}		
R_{240}		
MR_{120}		
MR_{240}		

Fig. 18.

Here M designates mirror image, or reflection in the vertical axis, R_j means clockwise rotation through j degrees, and I means identity. Hence the orders of these subgroups are $S_1 = 6$, $S_2 = 2$, and $S_3 = 2$.

$$D_6 = 2n \sum_{i=1}^{3} \frac{1}{S_i} = 12(1/6 + 1/2 + 1/2)$$

$$= 14.$$

These 14 ways of dissecting the hexagon (2 from type I and 6 each from types II and III) are shown in Fig. 19.

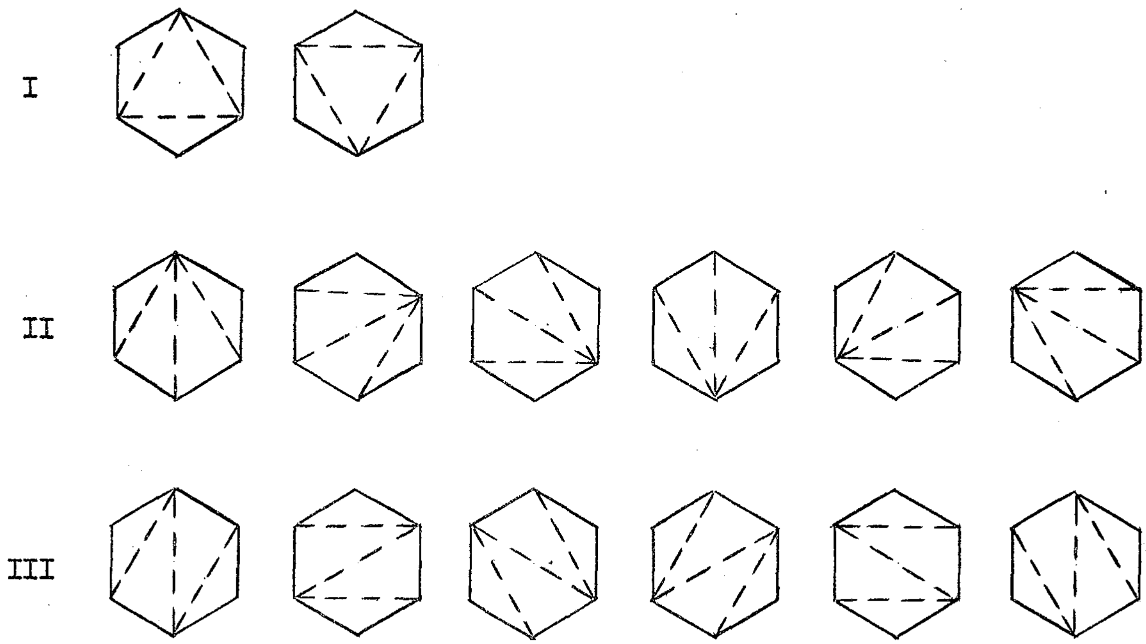


Fig. 19.

Explicit Formulae.

The Reverend Thomas P. Kirkman wrote many papers in the publications of the Philosophical Societies of Manchester and Liverpool, and the Royal Society of London, mostly in the 1850's, on the subject of polyhedra, especially on the "Kirkman polyhedra" discussed in the foregoing section. Kirkman developed a system of rather involved recursion formulas involving f_j (as defined above). There is, however, a particular case in which the formula becomes explicit and rather simple. The number of non-isomorphic polyhedra for which $F \geq 6$, $f_{F-1} = 1$, and $f_3 = 2$ is:

$$2^{\frac{F-8}{2}}\left(2^{\frac{F-6}{2}} + 1\right) \qquad \text{(F even)}$$

$$2^{\frac{F-7}{2}}\left(2^{\frac{F-7}{2}} + 1\right) \qquad \text{(F odd).}$$

See [17].

Enumeration.

Professor Oswald Hermes and Dr. J. Max Brückner both worked on the extensive enumeration of various subclasses of convex polyhedra. Their work leap-frogged, each having occasion to correct the other's results. Brückner's work culminated in a book, Vielecke und Vielflache, published in 1900, [1]. Subsequently he published papers adding to his results. In particular, at the Congresso Internazionale dei Matematici in Bologna in 1928 he reported certain results, saying in a footnote that the supporting manuscripts would be left to "some German university library." After some amount of correspondence, I finally located them at the University of Heidelberg in eighteen large volumes.[1]

The procedure used by both Hermes and Brückner was to cut off vertices, edges, or even pairs of intersecting edges from polyhedra of F faces to make polyhedra of F+1 faces. Many years of work went into the tabulation of polyhedra by these two men. The most recent results show the following total numbers of non-isomorphic polyhedra of various subclasses (Table 1). The notation is as follows. G stands for Gattung, or tribe, and P stands for polyhedra. The subscript shows the total number of faces, and the superscript shows the number of faces not contiguous with the base face. Since the base face is always chosen so that it has at least as many edges as any other face, $G^0_{11} = 30$ means that there are thirty tribes of 11-hedra having at least one 10-gonal face. Generally,

$$P_F \quad \text{and} \quad G_F$$

refer to the set of all non-isomorphic convex polyhedra with F faces,

[1] In the Handschriftenabteilung der Universitätsbibliothek Heidelberg, under the label "Heid. Hs. 964 bis 981."

P_F giving their number, and G_F the number of their tribes, whereas

$$P_F^c \quad \text{and} \quad G_F^c$$

refer only to the subset of those that have a base of F-1-c sides.

TABLE 1

BRÜCKNER'S NUMBERS FOR POLYHEDRA WITH MORE THAN TEN FACES

G_{11}^0	= 30	P_{11}^0	= 82
G_{11}^1	= 51	P_{11}^1	= 281
G_{11}^2	= 62	P_{11}^2	= 508
G_{11}^3	= 42	P_{11}^3	= 335
G_{11}^4	= 14	P_{11}^4	= 44
G_{11}	= 199	P_{11}	= 1250
G_{12}^0	= 50	P_{12}^0	= 228
G_{12}^1	= 91	P_{12}^1	= 991
G_{12}^2	= 120	P_{12}^2	= 2264
G_{12}^3	= 107	P_{12}^3	= 2826
G_{12}^4	= 61	P_{12}^4	= 1232
G_{12}^5	= 14	P_{12}^5	= 74
G_{12}^6	= 1	P_{12}^6	= 1
G_{12}	= 444	P_{12}	= 7616

G_{13}^0	= 88	P_{13}^0	= 731
G_{13}^1	= 154	P_{13}^1	= 3452
G_{13}^2	= 223	P_{13}^2	= 9401
G_{13}^3	= 224	P_{13}^3	= 16234
G_{13}^4	= 165	P_{13}^4	= 15218
G_{13}^5	= 76	P_{13}^5	= 4302
G_{13}^6	= 16	P_{13}^6	= 115
G_{13}	= 946	P_{13}	= 49453
G_{14}^0	= 140	P_{14}^0	= 2282
G_{14}^1	= 253	P_{14}^1	= 12170
G_{14}^2	= 359	P_{14}^2	= 37030
G_{14}^7	= 18	P_{14}^7	= 178
G_{15}^0	= 225	P_{15}^0	= 7531
G_{15}^1	= 339	P_{15}^1	= 45232
G_{15}^8	= 17	P_{15}^8	= 266
G_{16}^0	= 350	P_{16}^0	= 24312

CHAPTER III

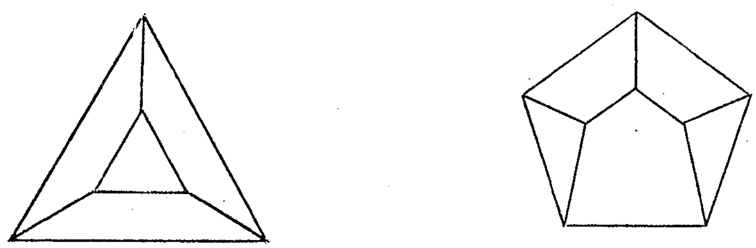
COMPUTATION

General Comments.

I have written a computer program in the "Extended Algol" language for the Burroughs B5000 computer [24]. The program starts with the tetrahedron, and performs all possible partitions of faces to form pentahedra, saving only those which are not equisurrounded to one saved previously; see the definition of "equisurrounded" in Chapter I. Then it uses the pentahedra as inputs, partitioning their faces to form hexahedra, then the hexahedra to form heptahedra, and so on. The original program was written to accommodate 11-hedra. Then when Brückner's 1928 paper [2] came to light, I modified the program enough to accommodate larger numbers of faces but of limited edge-count. Hence we have a complete enumeration of convex tri-linear polyhedra of up to 11 faces, and a partial enumeration (maximum edge-count ≤ 6) for $F = 12$, 13, 14, and 15.

Representation.

In partitioning a face of one of the input polyhedra, the representation of the polyhedron is the one labelled 4a in Chapter I, namely a list of the neighboring faces of each face, in cyclic order, by name. For comparing two polyhedra, however, 4b is used -- a list of the neighbors by edge-count rather than by name. To make such a description unique, it was necessary to agree on a canonical form for the latter representation. In my program I permuted the neighbors, retaining the cyclic order, until the resulting word was numerically minimized. Then these words, one for each face, were sorted to make one-to-one matching less laborious a process. Two examples are shown in Fig. 20.



444	455
444	455
3434	3545
3434	3545
3434	34435
	34435

Fig. 20.

Splitting.

Once it is determined which face is to be partitioned, and between which neighbors of that face the partition line is to run, the details of forming the resulting polyhedron simply amount to a great deal of bookkeeping. The procedure by which we assure that all possible partitions are made will be described here. We do the following for each face of each input polyhedron. Assume that the edges (and hence the neighbors) of the face being partitioned are numbered from 1 to N, counterclockwise, as in Fig. 21. We run a partition line from each edge to the next higher numbered edge, including the "wraparound" case from edge N to edge 1. This is referred to as cutting off one vertex.

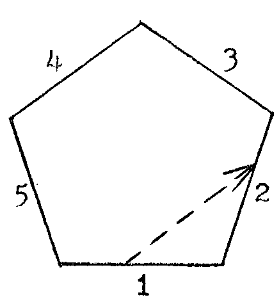


Fig. 21.

Next we run a partition line from each edge to the second higher numbered edge -- e.g. from 1 to 3, 2 to 4, etc., N to 2. This is referred to as cutting off two vertices. For example, in Fig. 22 the partition line runs from edge 4 to edge 1. We continue this process of cutting off

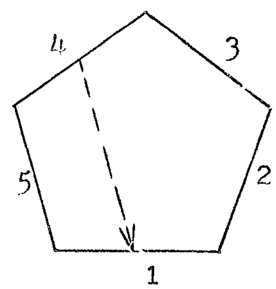


Fig. 22.

V vertices, where V ranges from 1 up to [N/2], the greatest integer contained in N/2. The reason we do not have to go higher is that, because of symmetry, higher values of V simply duplicate partitions that have already been made. For instance, in Fig. 23 the case of V = 3 gives the same partition as the previous one shown above.

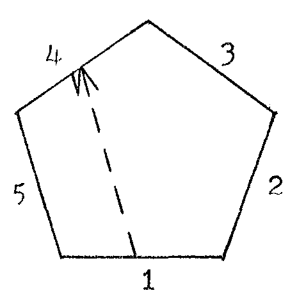


Fig. 23.

The recognition of one other form of symmetry seemed worthwhile in the program. That is, in a face having an even number of edges, N, the partition lines for V = N/2 need begin only at edges numbered from 1 through N/2.

Comparison.

The procedure by which the polyhedra created by the splitting process are checked for equivalence will now be described. First, the tribe number for the newly created polyhedron is formed by counting triangles, quadrilaterals, etc. The tribe is checked against the tribe numbers of each of the polyhedra already formed. If the new one is not found in storage, then no further checking is necessary -- the new one is added to the collection.

If, on the other hand, the new tribe number matches one or more of those in storage, then members of this matching subset of polyhedra are singled out for detailed comparison with the new polyhedron. The detailed comparison entails looking for an exact one-to-one matching of the sets of face "words" of the two polyhedra being compared. That is, they are checked to see if they are equisurrounded, as defined above in Chapter I. At any point in the comparison, if a face word of a polyhedron A is unequal to a face word of polyhedron B, then a new polyhedron from storage is brought out for comparison. Similarly, comparison checking for a new polyhedron can be terminated immediately upon finding a polyhedron in storage with which the new one is equisurrounded. If, however, no such polyhedron is found, then the new one has to be "turned inside out" by reversing the cyclic order of the neighbors of each face, and checking it against the set of polyhedra of the same tribe again. If it survives this test without being rejected as equisurrounded with one in storage, then it is added to the collection. Then the program returns to make another partition.

Thus, in fact, my computer program regards polyhedra as equivalent if, and only if, they are equisurrounded.

Results.

Using the above program on the Stanford University Burroughs B5000 computer, consisting of a 16,384 word core memory, two drums, four tape drives, two card readers, two printers, and a card punch, I created all the tri-linear convex polyhedra of up to eleven faces. This took about twelve hours of computer time. In comparing my results with those published by Brückner [1] enumerated by another method, I found that we agreed, one-for-one, up to the 10-hedra, which is as far as he went at that time. In his 1928 paper [2] he claims to have found 1250 or 1251 11-hedra, these two figures appearing in two different places in the paper. My results showed only 1249 11-hedra, but have not been compared in detail with Brückner's since the supporting manuscripts upon which his paper was based are in Heidelberg. I hope to have the proper pages of the manuscripts duplicated and sent to me, if practicable.

I should like to point out the evidence which gives credence to my results. Brückner and Hermes disagreed quite a bit on their enumeration of polyhedra before the turn of the century. Hermes even found an omission in Brückner's list of 10-hedra, fortunately in time to include the correction in the publication [1].

Another example of a difference with Brückner's results is in the number of 12-hedra with hexagonal base. He claims 74 as against my 76, and there is a provable omission on his part in this case, even without reference to his manuscripts. The number of tribes of this class of polyhedra is 14 according to Brückner, whereas I have found 15. It is sufficient proof of their existence to draw a representative for each tribe, as I have done in Fig. 24.

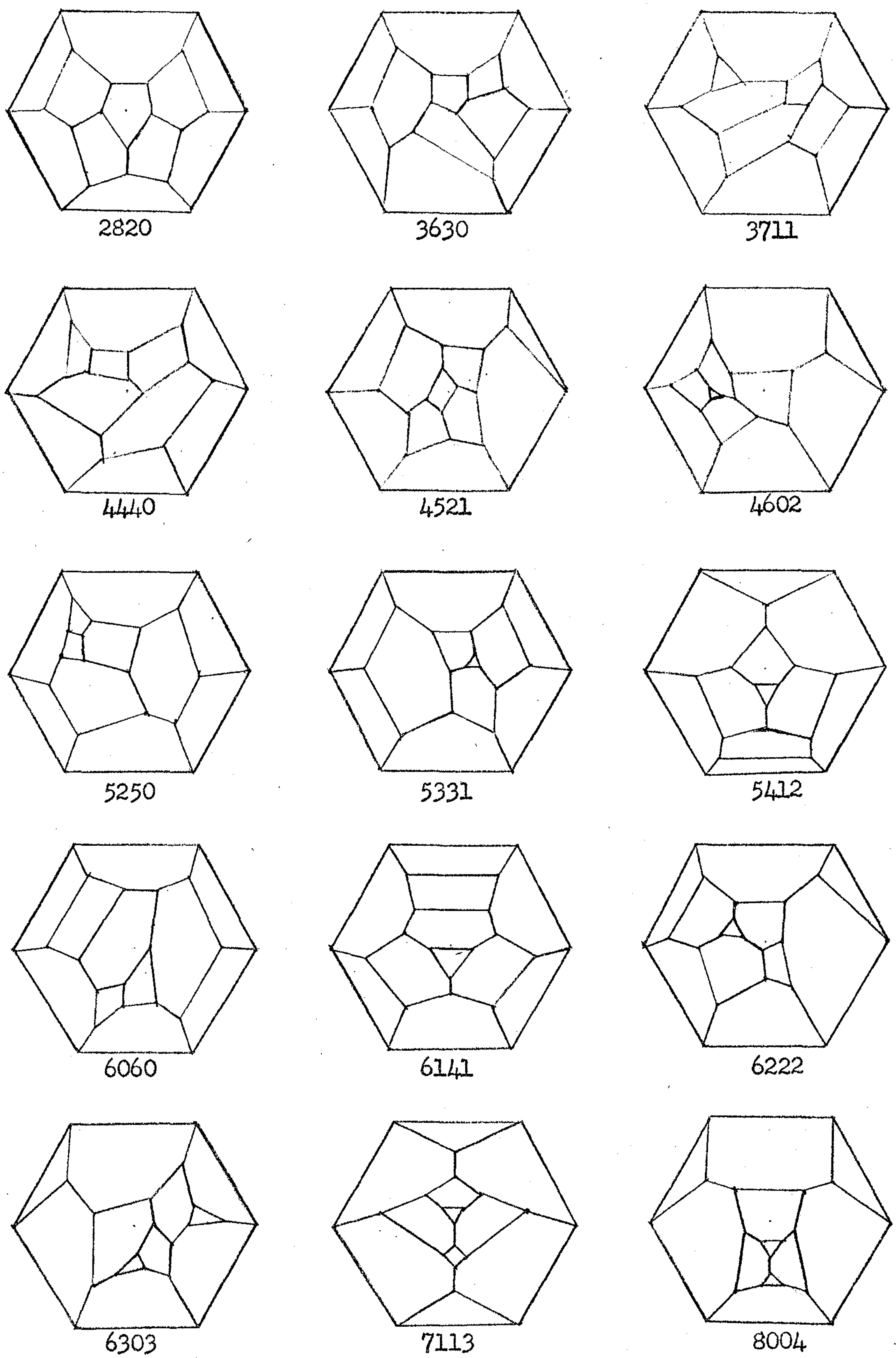


Fig. 24. Fifteen tribes of 12-hedra with maximum edge-count = 6.

In the section above called, "Kirkman polyhedra. Dissection of a Polygon into Triangles," we proved another error in Brückner's results, analytically rather than empirically.

Regarding the difference in the number of 11-hedra, the net difference of 1 between Brückner's 1250 and my 1249 polyhedra is a composite of two errors in certain subsets. For the number of 11-hedra with an octagonal base face (two faces in the polyhedron not contiguous with the base face) Brückner had 508 and I had 509. On the other hand, Brückner had 335 with a heptagonal base, whereas I had 333. These errors are in opposite directions, making a net discrepancy of 1.

As will be explained in Chapter IV, Testing Isomorphism, the criterion of equisurroundedness is a necessary but not sufficient condition for isomorphism of two polyhedra. If I had consistently found fewer polyhedra than Brückner then I would suspect that I had discarded some equisurrounded polyhedra which were, in fact, non-isomorphic. But the fact is that, except in the last cited case of the preceding paragraph, I consistently found more polyhedra than Brückner.

For purposes of comparison with the hand-work of Brückner and Hermes, I shall itemize my specific results in Table 2 and repeat theirs, where they differ from mine.

Recall that G stands for Gattung, or tribe, and P for polyhedra. The subscript shows the total number of faces, and the superscript shows the number of faces not contiguous with the base face. My results are shown, followed by Brückner's in parentheses where his differ from mine.

TABLE 2

SOME OF MY RESULTS COMPARED WITH THOSE OF BRÜCKNER

G_{11}^{0}	= 30	P_{11}^{0}	= 82
G_{11}^{1}	= 51	P_{11}^{1}	= 281
G_{11}^{2}	= 62	P_{11}^{2}	= 509 (508)
G_{11}^{3}	= 42	P_{11}^{3}	= 333 (335)
G_{11}^{4}	= 14	P_{11}^{4}	= 44
G_{11}	= 199	P_{11}	= 1249 (1250)
G_{12}^{5}	= 15 (14)	P_{12}^{5}	= 76 (74)
G_{12}^{6}	= 1	P_{12}^{6}	= 1 (reg. dodecahedron)
G_{13}^{6}	= 16	P_{13}^{6}	= 115
G_{14}^{7}	= 18	P_{14}^{7}	= 184 (178)
G_{15}^{8}	= 17	P_{15}^{8}	= 267 (266)

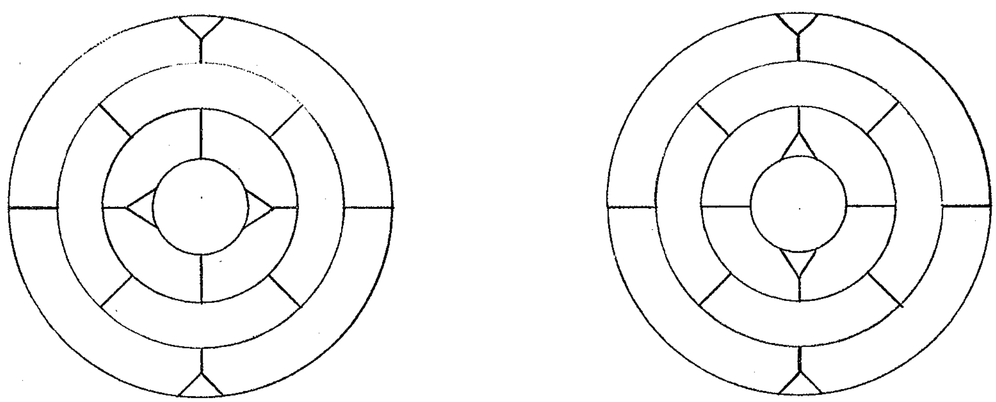
CHAPTER IV

TESTING ISOMORPHISM

The results of this work were obtained using "equisurroundedness" as the criterion for the equivalence of polyhedra. In the course of the work it turned out, however, that the following is true:

Theorem 10. Equisurroundedness is a necessary but not a sufficient condition for isomorphism.

The necessity is obvious, and the insufficiency is demonstrated by a counter-example. In a polyhedron having a large number of faces it is possible to isolate a symmetrical subset of faces in such a way that a perturbation can be made which does not alter the "surroundings" of the individual faces. The best example derived heretofore from this general idea is represented by Fig. 25. Each of the two polyhedra R and S has



Polyhedron R   Polyhedron S

Fig. 25.

eighteen faces deployed as follows: there are four hexagons forming a belt around the "equator" and two "polar caps" which look like the net of Fig. 26. In polyhedron S, the orientation of the two polar caps is "parallel," but in polyhedron R, one is rotated through 90 degrees with respect to the other, about the pole.

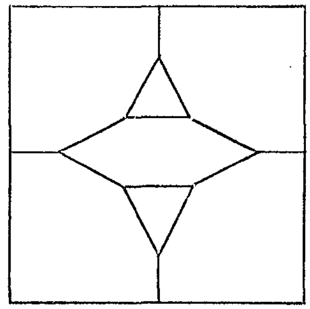


Fig. 26.

The present computer work includes only polyhedra of less than eighteen faces, yet we have no assurance that the criterion of equisurroundedness is sufficient for isomorphism even for such polyhedra. A counter-example of fewer faces could possibly be found. The experimental evidence makes this seem unlikely since I found more of the higher polyhedra than Brückner in some cases, and never less. However, unless an analytical proof were found, a complete test for isomorphism would be necessary even for those polyhedra already generated, and certainly for those with more faces. Such a test is considerably more time-consuming than the test for equisurroundedness since face labels can be interchanged in so many ways, in general. However, it is not quite as bad as it might seem, since only like faces need be interchanged. That is, we can make tests for necessary conditions, thereby making it possible to reject the hypothesis of isomorphism early, and proceed to the detailed exhaustive isomorphism test only in a relatively small number of cases.

If two polyhedra, R and S, are isomorphic, their faces must match with respect to certain properties. For instance, if face R_1 is to correspond to face S_1, then they must not only have the same number of edges, but also must adjoin like polygons -- i.e. be equisurrounded as faces. Therefore it is not necessary to form all possible permutations of the labels of the faces, but only permutations of like faces. The number of permutations becomes very much smaller in a hurry. For example, 18! might become 2!4!4!8!.

We want to devise a list of necessary conditions for faces which will lead us to a conclusion of non-isomorphism quickly, leaving very few polyhedra to be checked completely. First, the tribes of the two polyhedra must of course be the same. Secondly, they must be equisurrounded. Thirdly, a face pair, one from each of the polyhedra being compared, must have equisurrounded neighbors also. A decision to be made here is whether to use the separate edge-counts of each of these neighbors' neighbors, or just the total of same.

Suppose we have such a list of necessary conditions for two polyhedra, A and B. This classifies the faces of A and B into subsets having like properties. Assume that the correspondence, by properties, is as shown in the following property list:

Polyhedron A	Property	Polyhedron B
(1,2)	1	(3,5)
(4,6,7)	2	(1,2,4,7)
(3)	3	(6)
(5,8)	4	(8)

We can conclude immediately that the two polyhedra are non-isomorphic since the numbers of faces in the above subsets do not correspond. However, if such a list does have equal numbers of faces in the corresponding subsets, we would have to test further in a manner like this: Choose a small subset and assume a correspondence between one face of A and one face of B. For example, under property 1 above, assume face A_1 maps into face B_3. This changes the property list. Then further extensions of the face properties (e.g. neighbors' neighbors) being evaluated are made, thereby refining the property list still further. This leads either to a contradiction, proof of isomorphism, or no further refinement. In the case of a contradiction, non-isomorphism is proved. Proof of isomorphism comes when the property list contains only subsets of one element each. In the last case, when there is no further refinement, we make a further assumption of correspondence and repeat.

Note that, regardless of whether two polyhedra are equisurrounded in their original form, or when one is turned inside out, the labels on the faces might not correspond unless one is turned inside out. For example, without relabeling the faces we ought to be able to determine that the two tetrahedra of Fig. 27 are isomorphic. In both tetrahedra, the base face is face #1.

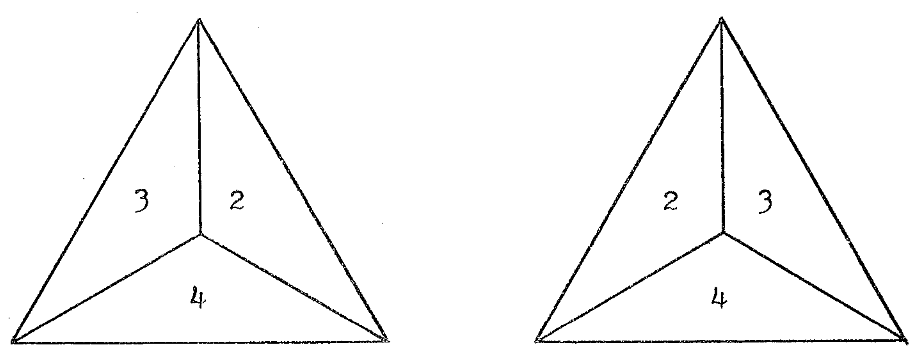


Fig. 27.

Now let us consider the eighteen-faced counter-example of Fig. 25, above, showing two polyhedra, R and S, which are equisurrounded but not isomorphic. Suppose we label the South Pole caps the same for the two polyhedra, as shown in Fig. 28. The numbers outside the cap are the labels of the adjoining faces -- the four hexagons around the equator.

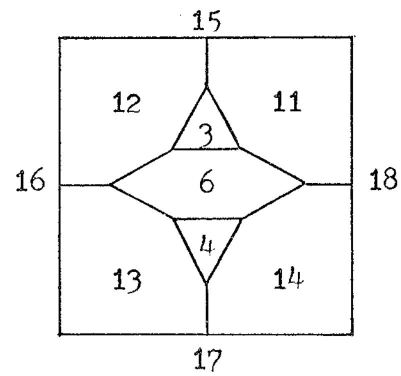


Fig. 28. Common South Pole.

For the North Pole caps, suppose we label the faces as shown in Fig. 29 for polyhedron R and polyhedron S. For this arrangement, the neighbors' edge-counts, listed under "Surroundings," and the neighbors' labels are shown in Table 3.

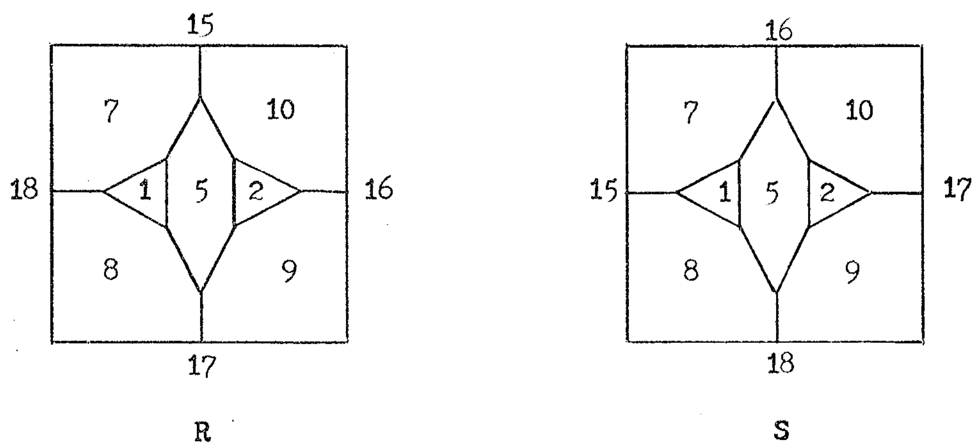


Fig. 29. North Poles.

TABLE 3

COMPUTER REPRESENTATION OF TWO SPECIAL 18-HEDRA

Face	Surroundings	R						S					
1	666				5	7	8				5	7	8
2	666				5	9	10				5	9	10
3	666				6	11	12				6	11	12
4	666				6	13	14				6	13	14
5	366366	1	8	9	2	10	7	1	8	9	2	10	7
6	"	3	12	13	4	14	11	3	12	13	4	14	11
7	366666	1	5	10	15	18	8	1	5	10	16	15	8
8	"	1	7	18	17	9	5	1	7	15	18	9	5
9	"	2	5	8	17	16	10	2	5	8	18	17	10
10	"	2	9	16	15	7	5	2	9	17	16	7	5
11	"	3	6	14	18	15	12	3	6	14	18	15	12
12	"	3	11	15	16	13	6	3	11	15	16	13	6
13	"	4	6	12	16	17	14	4	6	12	16	17	14
14	"	4	13	17	18	11	6	4	13	17	18	11	6
15	666666	7	10	16	12	11	18	7	16	12	11	18	8
16	"	9	17	13	12	15	10	7	10	17	13	12	15
17	"	8	18	14	13	16	9	9	18	14	13	16	10
18	"	7	15	11	14	17	8	8	15	11	14	17	9

For complete isomorphism testing, we need to permute the labels on one of the polyhedra and see if the result is identical with the other. Those with the same "surroundings" in the table are the ones which need to be permuted. Thus, we have to permute the labels on the faces within the subsets: (1,2,3,4); (5,6); (7,8,...13,14); and (15,16,17,18). There are 24.2.40320.24 ways to do this -- about 45 million. Even for smaller polyhedra, e.g. nine faces, the heptagonal prism requires 7!2! = 10,080 permutations. Because of the symmetry, the cardinality of the subsets is not reduced by most of the extensions of properties described above.

To be feasible, perhaps such a complete isomorphism test must wait for the next generation of computers.

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APPENDIX

Explanation of Appendix.

The appendix consists of two parts -- the listing of the computer program in Burroughs B5000 Extended Algol, followed by the enumeration of polyhedra produced by the computer. Because of the large volume of output it was necessary to code the list of polyhedra rather cryptically. A word of explanation is in order. Maximum edge-count is abbreviated MEC.

Each line of print in the list represents one polyhedron. The line bears the identification number (they are numbered serially) of the polyhedron, followed by one coded word for each face of the polyhedron, in order, beginning with face #1. Each word consists of n digits, where n is the number of sides of that face. The digits identify the adjoining faces in clockwise order. For polyhedra having more than 9 faces, the character "A" stands for 10, B for 11, etc. An example will help clarify the coding. Take polyhedron #1 from the list of 11-hedra on page 86. A clearer listing of its 11 faces is shown in Table 4.

TABLE 4

FIRST 11-HEDRON

Face Number	Number of Sides	Identification of Neighbors in Clockwise Order
1	8	4 3 8 6 9 10 11 2
2	8	10 9 6 5 3 4 1 11
3	5	4 2 5 8 1
4	3	3 1 2
5	5	7 8 3 2 6
6	6	7 5 2 9 1 8
7	3	8 5 6
8	5	7 6 1 3 5
9	4	10 1 6 2
10	4	9 2 11 1
11	3	10 2 1

COMPUTER PROGRAM

```
BEGIN COMMENT             D. W. GRACE              BIN 141
     EXT. 4425,      POLYHEDRON PARTITIONING PROBLEM
THINGS TO REMEMBER TO CHANGE BEFORE RUNNING
     THE DATA CARD CONTAINING F, PMAX, I, MS, AND ML.
     THE GMAX ASSIGNMENT STATEMENT -- THE FIRST EXECUTED STATEMENT.   ;
LABEL B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, FINALEND, GENESIS, ILOOP,
      MSMT, MLMT, MSZERO, MLZERO, POK, RESTART, READALL, START;
SWITCH SW6 ← B1, B2, B3, B4, B5, B6, B7, B8, B9, B10;
BOOLEAN BOOLIO, BOOL;
INTEGER A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, ALF, BAD, BAM, CNTL,
      DEL, DIM, F, FREQ, G, GMAX, I, J, JOE, K, LIXO, LIXM, MCH, ML, MS,
      N, PATJS, PATJT, PMAX, PRMINDEX, QINDEX, S, SAM, SIXO, SIXM, T,
      T1, TOTCOUNT, U, V, VM, VMAX, W, X, Y, Z;
REAL ARRAY COUNT[0:10], DELSAVE[0:11], DELTA[0:11],FREQL[0:1,0:700],
      FREQS[0:1022], MATCH[0:200], P[0:10], PRM[0:9], Q[0:11],
      QL[0:225,0:10],QS[0:125,0:10],QLD[0:14, 0:1013],QSD[0:12, 0:1013];
SAVE ARRAY INQ[0:11], PAT[0:11, 0:16],  QAT[0:11, 0:11];
ALPHA ARRAY CHAR[0:15];
FILE LP(2,15), PFIL 2(1,15,SAVE 099), QLDFIL 2(1,15,SAVE 099),
      QSDFIL 2(1, 15, SAVE 099);
FORMAT FMT1("FACE J =",I3,"NOT FOUND AS NABOR IN FACE WORD ",2A6);
FORMAT FMT2("TRIBE ", 11A1);
FORMAT FMT4 ("START TO MAKE ",I3,"-HEDRA FROM ",I3,"-HEDRA.");
FORMAT FMT6(X12, I1, X16, I2, X11, I2, X6, 10(A1, "-", A1, X2) ) ;
FORMAT FMT9(X5, "ELAPSED EXECUTION TIME IS", F8.2, " MINUTES. RESTART PA
RAMETER I IS NOW", I4, ".");
FORMAT FMT10(X5, "L POLY NO. FOLLOWED BY ITS QLD.",I4,X2,  11(A6,X1));
FORMAT FMT11(X5, "S POLY NO. FOLLOWED BY ITS QSD.",I4,X2,  11(A6,X1));
FORMAT FMT12(X5, "PERMUTE RIGHT    NUMBER OF SIDES    FACE    CLOCKWISE
NEIGHBORS (ID. NO.)-(NO. OF SIDES)     NOTE: #=10, @=11.");
FORMAT FMT13(X5, "POLY", I4, " FACE", I2, " WITH V =", I2, " AND S =",
I3, ".   RESTART PARAMETERS F, PMAX, I, MS, AND ML ARE",I3,I4,I4,I5,I5);
FORMAT FMT15(/"EXECUTION TIME EXCLUSIVE OF COMPILATION WAS ",F9.2,
      " MINUTES.");
FORMAT FMT16("RESTART USING PARAMETERS F =",I3,"  PMAX =",I4,  "  I =",
     I4, "  MS =", I5, "  AND ML =", I5);
FORMAT FMT17("PFIL MESSED UP.  I =", I4, " NOT EQUAL TO P[0] =",I4);
FORMAT FMT91(I5, X1,93A1);
FORMAT FMT92(X99, I3, I4, I4, I5, I5);
PROCEDURE PARTITION     ;
BEGIN
    LABEL ERR1, ENDPART, END8, END10,  END11, BIGT, STNEXT;
    T ← V+S ; COMMENT T = SUBSCRIPT OF TERMINAL NABOR BUT NOT MOD N. ;
    COMMENT S = SUBSCRIPT OF STARTING NABOR, AND V = NO. VERTS CUT OFF.;
    FOR Y ← 1 STEP 1 UNTIL F DO
    BEGIN JOE ← PAT[Y,0];
     FOR Z ← 0 STEP 1 UNTIL JOE DO QAT[Y,Z] ← PAT[Y,Z];
    END; COMMENT NOW MAKE CORRECTIONS TO QAT CAUSED BY PARTITION.   ;
    QAT[G,0] ← V + 2;  COMMENT NEW FACE HAS V + 2 EDGES.    ;
    QAT[G,1] ← J;
    FOR Z ← 0 STEP 1 UNTIL V DO QAT[G,Z+2] ← PAT[J,Z + S];
    BAM ← V - 2;
    JOE ← QAT [J, 0] ← N - BAM;
```

```
    COMMENT  CUT FACE HAS N-V+2 EDGES.                                    .
    IF N < 1 THEN GO TO BIGT;                                             .
    QAT [J, S + 1] ← G;   COMMENT  THE FIRST S NABORS ARE UNCHANGED.;     .
    FOR Z ← S + 2 STEP 1 UNTIL JOE DO QAT [J, Z] ← PAT [J, BAM + Z];      .
    GO TO STNEXT;                                                         .
    COMMENT  GO AHEAD AND ADJUST NABORS S AND T NEXT.   ;                 .
    BIGT: COMMENT                              BIGT: ;                    .
    QAT [J, 1] ← G;                                                       .
    BAM ← (T MOD N) - 2;                                                  .
    FOR Z ← 2 STEP 1 UNTIL JOE DO QAT [J, Z] ← PAT [J, BAM + Z];          .
    COMMENT NEW FACE, G, REPLACED ALL NABORS OF CUT FACE ENTRE S AND T.;. 
    STNEXT: COMMENT                                   STNEXT: ;           .
    PATJS ← PAT [J, S];                                                   .
    COMMENT  PATJS = NABOR NUMBER S OF FACE J.   ;                        .
    JOE ← PAT [PATJS, 0];                                                 .
    QAT [PATJS, 0] ← JOE + 1;                                             .
    FOR Z ← 1 STEP 1 UNTIL JOE DO IF QAT [PATJS, Z] = J THEN              .
    BEGIN FOR Y←JOE STEP -1 UNTIL Z DO QAT[PATJS,Y+1]←QAT[PATJS,Y];       .
       GO TO END11;                                                       .
    END;                                                                  .
    END11: COMMENT                                      END11:;           .
    QAT [PATJS, Z] ← G;                                                   .
    COMMENT  QAT[PATJS,0] = DIMENSION OF NABOR S.            NOTICE THAT  .
    T MAY BE BIGGER THAN N BECAUSE OF THE WRAP-AROUND FEATURE. ;          .
    PATJT ← PAT [J, T]; COMMENT   PATJT = NABOR NUMBER T OF FACE J.    ;. 
    JOE ← PAT [PATJT, 0]; COMMENT  DIMENSION OF NABOR T.   ;              .
    QAT [PATJT, 0] ← JOE + 1;                                             .
    FOR Z ← 1 STEP 1 UNTIL JOE DO IF QAT [PATJT, Z] = J THEN              .
    BEGIN FOR Y ← JOE - 1 STEP - 1 UNTIL Z DO QAT [PATJT, Y + 2] ←        .
       QAT[PATJT, Y + 1];                                                 .
       GO TO END10;                                                       .
    END;                                                                  .
    END10: COMMENT                                       END10: ;         .
    QAT [PATJT, Z + 1] ← G;  COMMENT  EDGE/COUNT OF NEIGHBOUR T.  ;       .
    FOR Z ← 2 STEP 1 UNTIL V DO                                           .
    BEGIN U ← PAT [J, S + Z - 1];                                         .
       COMMENT  U = ID OF NABOR NO. S+Z-1 OF FACE J.   ;                  .
       COMMENT   THAT IS, WE DO THIS FOR NABOR NO. S+1, S+2,...T-1. ;     .
       FOR Y ← 1 STEP 1 UNTIL QAT [U, 0] DO IF QAT [U, Y] = J THEN        .
       BEGIN QAT [U, Y] ← G; GO TO END8; END;                             .
       BAD ← QAT [U, Y];                                                  .
       ERR1: WRITE (LP, FMT1, J, BAD . [4 : 20], BAD . [24 : 24]);        .
    END8:  END;   COMMENT                                     END8: ;     .
ENDPART: END;    COMMENT END OF PROCEDURE PARTITION.          ENDPART:;.
PROCEDURE ISOCHECK;                                                       .
BEGIN                                                                     .
    LABEL CANON, E3, E4, E5, E6, E7, E8, E9, E10,ENDISO,END5, FILLQSD,    .
       L3, L4, L5, L6, L7, L8, L9, L10, MAKEPRM, PICKPRM, STARTPRM,SORT;. 
    SWITCH SW2 ← L3, L4, L5, L6, L7, L8, L9, L10;                         .
    SWITCH SW7 ← E3, E4, E5, E6, E7, E8, E9, E10;                         .
    FORMAT FMT14 ("TCTCOUNT ERROR.", I2, X5, 15 (I2, X1));                .
    BOOL10 ← FALSE;                                                       .
    LIXD ← (ML+1) DIV 92;                                                 .
    LIXM ← ((ML+1) MOD 92) × 11;                                          .
    SIXD ← (MS+1) DIV 92;                                                 .
```

```
SIXM ← ((MS+1) MOD 92) × 11;
FOR Z ← 3 STEP 1 UNTIL F DO COUNT [Z] ← 0;
FOR Z ← 1 STEP 1 UNTIL G DO COMMENT     FOR EACH FACE.       ;
BEGIN DIM ← QAT [Z, 0];
   COUNT [DIM] ← COUNT [DIM] + 1;
END;
TOTCOUNT ← 0;
FOR Z ← 3 STEP 1 UNTIL F DO TOTCOUNT ← TOTCOUNT + COUNT [Z];
IF TOTCOUNT = G THEN GO TO CANON;
WRITE (LP, FMT14, TOTCOUNT, FOR Z ← 1 STEP 1 UNTIL 15 DO COUNT [Z]);
CANON: COMMENT                                              CANON:;
CNTL ← COUNT[F] + COUNT[F-1];
COMMENT  NOW WE FORM ALL POSSIBLE PERMUTATIONS OF THE NABORS EDGE-
COUNTS AND PICK THE NUMERICALLY SMALLEST FOR OUR CANONICAL FORM. ;
STARTPRM: COMMENT                                        STARTPRM:;
FOR Z ← 1 STEP 1 UNTIL G DO COMMENT       FOR EACH FACE.      ;
BEGIN DIM ← QAT [Z, 0];
   PRMINDEX ← DIM - 1;
   IF BOOLIO THEN GO TO SW7 [DIM - 2]; COMMENT E3, ..., E10. ;
   A10 ← QAT [QAT [Z, 10], 0];
   A9 ← QAT [QAT [Z, 9], 0];
   A8 ← QAT [QAT [Z, 8], 0];
   A7 ← QAT [QAT [Z, 7], 0];
   A6 ← QAT [QAT [Z, 6], 0];
   A5 ← QAT [QAT [Z, 5], 0];
   A4 ← QAT [QAT [Z, 4], 0];
   A3 ← QAT [QAT [Z, 3], 0];
   A2 ← QAT [QAT [Z, 2], 0];
   A1 ← QAT [QAT [Z, 1], 0];
   GO TO MAKEPRM;
   E10: A10 ← QAT [QAT [Z, DIM - 9], 0];
   E9: A9 ← QAT [QAT [Z, DIM - 8], 0];
   E8: A8 ← QAT [QAT [Z, DIM - 7], 0];
   E7: A7 ← QAT [QAT [Z, DIM - 6], 0];
   E6: A6 ← QAT [QAT [Z, DIM - 5], 0];
   E5: A5 ← QAT [QAT [Z, DIM - 4], 0];
   E4: A4 ← QAT [QAT [Z, DIM - 3], 0];
   E3: A3 ← QAT [QAT [Z, DIM - 2], 0];
   A2 ← QAT [QAT [Z, DIM - 1], 0];
   A1 ← QAT [QAT [Z, DIM], 0];
   DELSAVE [Z] ← DELTA [Z];
   COMMENT   MUST SAVE THE DELTAS WHILE DOING INSIDE-OUT CHECK.   ;
   MAKEPRM: COMMENT                                    MAKEPRM:;
   GO TO SW2 [DIM - 2];
   L10: COMMENT                                           L10:;
   PRM [0] ← 0 & A10 [8 : 44 : 4] & A9 [12 : 44 : 4] & A8 [16 : 44
   : 4] & A7 [20 : 44 : 4] & A6 [24 : 44 : 4] & A5 [28 : 44 : 4] &
   A4[32 : 44 : 4] & A3[36 : 44 : 4] & A2[40 : 44 :4] & A1[44:44:4];
   PRM [1] ← 0 & A1 [8 : 44 : 4] & A10 [12 : 44 : 4] & A9 [16 : 44
   : 4] & A8 [20 : 44 : 4] & A7 [24 : 44 : 4] & A6 [28 : 44 : 4] &
   A5[32 : 44 : 4] & A4[36 : 44 : 4] & A3[40 : 44 :4] & A2[44:44:4];
   PRM [2] ← 0 & A2 [8 : 44 : 4] & A1 [12 : 44 : 4] & A10 [16 : 44
   : 4] & A9 [20 : 44 : 4] & A8 [24 : 44 : 4] & A7 [28 : 44 : 4] &
   A6[32 : 44 : 4] & A5[36 : 44 : 4] & A4[40 : 44 :4] & A3[44:44:4];
   PRM [3] ← 0 & A3 [8 : 44 : 4] & A2 [12 : 44 : 4] & A1 [16 : 44
```

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: 4] & A10 [20 : 44 : 4] & A9 [24 : 44 : 4] & A8 [28 : 44 : 4]
& A7[32 : 44 :4] & A6[36 : 44: 4] & A5[40 : 44 :4] & A4[44:44:4]];
PRM [4] ← 0 & A4 [8 : 44 : 4] & A3 [12 : 44 : 4] & A2 [16 : 44
: 4] & A1 [20 : 44 : 4] & A10 [24 : 44 : 4] & A9 [28 : 44 : 4]
& A8[32 : 44 :4] & A7[36 : 44: 4] & A6[40 : 44 :4] & A5[44:44:4]];
PRM [5] ← 0 & A5 [8 : 44 : 4] & A4 [12 : 44 : 4] & A3 [16 : 44
: 4] & A2 [20 : 44 : 4] & A1 [24 : 44 : 4] & A10 [28 : 44 : 4]
& A9[32 : 44 :4] & A8[36 : 44: 4] & A7[40 : 44 :4] & A6[44:44:4]];
PRM [6] ← 0 & A6 [8 : 44 : 4] & A5 [12 : 44 : 4] & A4 [16 : 44
: 4] & A3 [20 : 44 : 4] & A2 [24 : 44 : 4] & A1 [28 : 44 : 4]
& A10[32: 44 :4] & A9[36 : 44: 4] & A8[40 : 44 :4] & A7[44:44:4]];
PRM [7] ← 0 & A7 [8 : 44 : 4] & A6 [12 : 44 : 4] & A5 [16 : 44
: 4] & A4 [20 : 44 : 4] & A3 [24 : 44 : 4] & A2 [28 : 44 : 4] &
A1 [32: 44 :4] & A10[36: 44: 4] & A9[40 : 44 :4] & A8[44:44:4]];
PRM [8] ← 0 & A8 [8 : 44 : 4] & A7 [12 : 44 : 4] & A6 [16 : 44
: 4] & A5 [20 : 44 : 4] & A4 [24 : 44 : 4] & A3 [28 : 44 : 4] &
A2 [32: 44 :4] & A1 [36: 44: 4] & A10[40: 44 :4] & A9[44:44:4]];
PRM [9] ← 0 & A9 [8 : 44 : 4] & A8 [12 : 44 : 4] & A7 [16 : 44
: 4] & A6 [20 : 44 : 4] & A5 [24 : 44 : 4] & A4 [28 : 44 : 4] &
A3 [32: 44 :4] & A2 [36: 44: 4] & A1 [40: 44 :4] & A10[44:44:4]];
GO TO PICKPRM;
L9: COMMENT                                               L9:;
PRM [0] ← 0 & A9 [12 : 44 : 4] & A8 [16 : 44 : 4] & A7 [20 : 44
: 4] & A6 [24 : 44 : 4] & A5 [28 : 44 : 4] & A4 [32 : 44 : 4] &
A3 [36 : 44 : 4] & A2 [40 : 44 : 4] & A1 [44 : 44 : 4];
PRM [1] ← 0 & A1 [12 : 44 : 4] & A9 [16 : 44 : 4] & A8 [20 : 44
: 4] & A7 [24 : 44 : 4] & A6 [28 : 44 : 4] & A5 [32 : 44 : 4] &
A4 [36 : 44 : 4] & A3 [40 : 44 : 4] & A2 [44 : 44 : 4];
PRM [2] ← 0 & A2 [12 : 44 : 4] & A1 [16 : 44 : 4] & A9 [20 : 44
: 4] & A8 [24 : 44 : 4] & A7 [28 : 44 : 4] & A6 [32 : 44 : 4] &
A5 [36 : 44 : 4] & A4 [40 : 44 : 4] & A3 [44 : 44 : 4];
PRM [3] ← 0 & A3 [12 : 44 : 4] & A2 [16 : 44 : 4] & A1 [20 : 44
: 4] & A9 [24 : 44 : 4] & A8 [28 : 44 : 4] & A7 [32 : 44 : 4] &
A6 [36 : 44 : 4] & A5 [40 : 44 : 4] & A4 [44 : 44 : 4];
PRM [4] ← 0 & A4 [12 : 44 : 4] & A3 [16 : 44 : 4] & A2 [20 : 44
: 4] & A1 [24 : 44 : 4] & A9 [28 : 44 : 4] & A8 [32 : 44 : 4] &
A7 [36 : 44 : 4] & A6 [40 : 44 : 4] & A5 [44 : 44 : 4];
PRM [5] ← 0 & A5 [12 : 44 : 4] & A4 [16 : 44 : 4] & A3 [20 : 44
: 4] & A2 [24 : 44 : 4] & A1 [28 : 44 : 4] & A9 [32 : 44 : 4] &
A8 [36 : 44 : 4] & A7 [40 : 44 : 4] & A6 [44 : 44 : 4];
PRM [6] ← 0 & A6 [12 : 44 : 4] & A5 [16 : 44 : 4] & A4 [20 : 44
: 4] & A3 [24 : 44 : 4] & A2 [28 : 44 : 4] & A1 [32 : 44 : 4] &
A9 [36 : 44 : 4] & A8 [40 : 44 : 4] & A7 [44 : 44 : 4];
PRM [7] ← 0 & A7 [12 : 44 : 4] & A6 [16 : 44 : 4] & A5 [20 : 44
: 4] & A4 [24 : 44 : 4] & A3 [28 : 44 : 4] & A2 [32 : 44 : 4] &
A1 [36 : 44 : 4] & A9 [40 : 44 : 4] & A8 [44 : 44 : 4];
PRM [8] ← 0 & A8 [12 : 44 : 4] & A7 [16 : 44 : 4] & A6 [20 : 44
: 4] & A5 [24 : 44 : 4] & A4 [28 : 44 : 4] & A3 [32 : 44 : 4] &
A2 [36 : 44 : 4] & A1 [40 : 44 : 4] & A9 [44 : 44 : 4];
GO TO PICKPRM;
L8: COMMENT                                               L8:;
PRM [0] ← 0 & A8 [16 : 44 : 4] & A7 [20 : 44 : 4] & A6 [24 : 44
: 4] & A5 [28 : 44 : 4] & A4 [32 : 44 : 4] & A3 [36 : 44 : 4] &
A2 [40 : 44 : 4] & A1 [44 : 44 : 4];
PRM [1] ← 0 & A1 [16 : 44 : 4] & A8 [20 : 44 : 4] & A7 [24 : 44
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: 4] & A6 [28 : 44 : 4] & A5 [32 : 44 : 4] & A4 [36 : 44 : 4] &
A3 [40 : 44 : 4] & A2 [44 : 44 : 4];
PRM [2] ← 0 & A2 [16 : 44 : 4] & A1 [20 : 44 : 4] & A8 [24 : 44
: 4] & A7 [28 : 44 : 4] & A6 [32 : 44 : 4] & A5 [36 : 44 : 4] &
A4 [40 : 44 : 4] & A3 [44 : 44 : 4];
PRM [3] ← 0 & A3 [16 : 44 : 4] & A2 [20 : 44 : 4] & A1 [24 : 44
: 4] & A8 [28 : 44 : 4] & A7 [32 : 44 : 4] & A6 [36 : 44 : 4] &
A5 [40 : 44 : 4] & A4 [44 : 44 : 4];
PRM [4] ← 0 & A4 [16 : 44 : 4] & A3 [20 : 44 : 4] & A2 [24 : 44
: 4] & A1 [28 : 44 : 4] & A8 [32 : 44 : 4] & A7 [36 : 44 : 4] &
A6 [40 : 44 : 4] & A5 [44 : 44 : 4];
PRM [5] ← 0 & A5 [16 : 44 : 4] & A4 [20 : 44 : 4] & A3 [24 : 44
: 4] & A2 [28 : 44 : 4] & A1 [32 : 44 : 4] & A8 [36 : 44 : 4] &
A7 [40 : 44 : 4] & A6 [44 : 44 : 4];
PRM [6] ← 0 & A6 [16 : 44 : 4] & A5 [20 : 44 : 4] & A4 [24 : 44
: 4] & A3 [28 : 44 : 4] & A2 [32 : 44 : 4] & A1 [36 : 44 : 4] &
A8 [40 : 44 : 4] & A7 [44 : 44 : 4];
PRM [7] ← 0 & A7 [16 : 44 : 4] & A6 [20 : 44 : 4] & A5 [24 : 44
: 4] & A4 [28 : 44 : 4] & A3 [32 : 44 : 4] & A2 [36 : 44 : 4] &
A1 [40 : 44 : 4] & A8 [44 : 44 : 4];
GO TO PICKPRM;
L7: COMMENT                                              L7:;
PRM [0] ← 0 & A7 [20 : 44 : 4] & A6 [24 : 44 : 4] & A5 [28 : 44
: 4] & A4 [32 : 44 : 4] & A3 [36 : 44 : 4] & A2 [40 : 44 : 4] &
A1 [44 : 44 : 4];
PRM [1] ← 0 & A1 [20 : 44 : 4] & A7 [24 : 44 : 4] & A6 [28 : 44
: 4] & A5 [32 : 44 : 4] & A4 [36 : 44 : 4] & A3 [40 : 44 : 4] &
A2 [44 : 44 : 4];
PRM [2] ← 0 & A2 [20 : 44 : 4] & A1 [24 : 44 : 4] & A7 [28 : 44
: 4] & A6 [32 : 44 : 4] & A5 [36 : 44 : 4] & A4 [40 : 44 : 4] &
A3 [44 : 44 : 4];
PRM [3] ← 0 & A3 [20 : 44 : 4] & A2 [24 : 44 : 4] & A1 [28 : 44
: 4] & A7 [32 : 44 : 4] & A6 [36 : 44 : 4] & A5 [40 : 44 : 4] &
A4 [44 : 44 : 4];
PRM [4] ← 0 & A4 [20 : 44 : 4] & A3 [24 : 44 : 4] & A2 [28 : 44
: 4] & A1 [32 : 44 : 4] & A7 [36 : 44 : 4] & A6 [40 : 44 : 4] &
A5 [44 : 44 : 4]:
PRM [5] ← 0 & A5 [20 : 44 : 4] & A4 [24 : 44 : 4] & A3 [28 : 44
: 4] & A2 [32 : 44 : 4] & A1 [36 : 44 : 4] & A7 [40 : 44 : 4] &
A6 [44 : 44 : 4];
PRM [6] ← 0 & A6 [20 : 44 : 4] & A5 [24 : 44 : 4] & A4 [28 : 44
: 4] & A3 [32 : 44 : 4] & A2 [36 : 44 : 4] & A1 [40 : 44 : 4] &
A7 [44 : 44 : 4];
GO TO PICKPRM;
L6: COMMENT                                              L6:;
PRM [0] ← 0 & A6 [24 : 44 : 4] & A5 [28 : 44 : 4] & A4 [32 : 44
: 4] & A3 [36 : 44 : 4] & A2 [40 : 44 : 4] & A1 [44 : 44 : 4];
PRM [1] ← 0 & A1 [24 : 44 : 4] & A6 [28 : 44 : 4] & A5 [32 : 44
: 4] & A4 [36 : 44 : 4] & A3 [40 : 44 : 4] & A2 [44 : 44 : 4];
PRM [2] ← 0 & A2 [24 : 44 : 4] & A1 [28 : 44 : 4] & A6 [32 : 44
: 4] & A5 [36 : 44 : 4] & A4 [40 : 44 : 4] & A3 [44 : 44 : 4];
PRM [3] ← 0 & A3 [24 : 44 : 4] & A2 [28 : 44 : 4] & A1 [32 : 44
: 4] & A6 [36 : 44 : 4] & A5 [40 : 44 : 4] & A4 [44 : 44 : 4];
PRM [4] ← 0 & A4 [24 : 44 : 4] & A3 [28 : 44 : 4] & A2 [32 : 44
: 4] & A1 [36 : 44 : 4] & A6 [40 : 44 : 4] & A5 [44 : 44 : 4];
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    PRM [5] ← 0 & A5 [24 : 44 : 4] & A4 [28 : 44 : 4] & A3 [32 : 44   .
    : 4] & A2 [36 : 44 : 4] & A1 [40 : 44 : 4] & A6 [44 : 44 : 4]];   .
    GO TO PICKPRM;                                                     .
    L5: COMMENT                                            L5:;        .
    PRM [0] ← 0 & A5 [28 : 44 : 4] & A4 [32 : 44 : 4] & A3 [36 : 44   .
    : 4] & A2 [40 : 44 : 4] & A1 [44 : 44 : 4]];                       .
    PRM [1] ← 0 & A1 [28 : 44 : 4] & A5 [32 : 44 : 4] & A4 [36 : 44   .
    : 4] & A3 [40 : 44 : 4] & A2 [44 : 44 : 4]];                       .
    PRM [2] ← 0 & A2 [28 : 44 : 4] & A1 [32 : 44 : 4] & A5 [36 : 44   .
    : 4] & A4 [40 : 44 : 4] & A3 [44 : 44 : 4]];                       .
    PRM [3] ← 0 & A3 [28 : 44 : 4] & A2 [32 : 44 : 4] & A1 [36 : 44   .
    : 4] & A5 [40 : 44 : 4] & A4 [44 : 44 : 4]];                       .
    PRM [4] ← 0 & A4 [28 : 44 : 4] & A3 [32 : 44 : 4] & A2 [36 : 44   .
    : 4] & A1 [40 : 44 : 4] & A5 [44 : 44 : 4]];                       .
    GO TO PICKPRM;                                                     .
    L4: COMMENT                                            L4:;        .
    PRM [0] ← 0 & A4 [32 : 44 : 4] & A3 [36 : 44 : 4] & A2 [40 : 44   .
    : 4] & A1 [44 : 44 : 4]];                                          .
    PRM [1] ← 0 & A1 [32 : 44 : 4] & A4 [36 : 44 : 4] & A3 [40 : 44   .
    : 4] & A2 [44 : 44 : 4]];                                          .
    PRM [2] ← 0 & A2 [32 : 44 : 4] & A1 [36 : 44 : 4] & A4 [40 : 44   .
    : 4] & A3 [44 : 44 : 4]];                                          .
    PRM [3] ← 0 & A3 [32 : 44 : 4] & A2 [36 : 44 : 4] & A1 [40 : 44   .
    : 4] & A4 [44 : 44 : 4]];                                          .
    GO TO PICKPRM;                                                     .
    L3: COMMENT                                            L3:;        .
    PRM [0] ← 0 & A3 [36 : 44 : 4] & A2 [40 : 44 : 4] & A1 [44:44:4]];.
    PRM [1] ← 0 & A1 [36 : 44 : 4] & A3 [40 : 44 : 4] & A2 [44:44:4]];.
    PRM [2] ← 0 & A2 [36 : 44 : 4] & A1 [40 : 44 : 4] & A3 [44:44:4]];.
    GO TO PICKPRM;                                                     .
    PICKPRM: COMMENT                                   PICKPRM:;       .
    DELTA [Z] ← 0;                                                     .
    FOR Y ← 1 STEP 1 UNTIL PRMINDEX DO COMMENT  PRMINDEX=QAT[Z,0]-1.;.
       IF PRM[Y] < PRM[DELTA[Z]] THEN  DELTA[Z] ← Y;                   .
    COMMENT  RECALL THAT WE SET DELTA TO ZERO ABOVE.                   .
    NOW DELTA CONTAINS THE PHASE SHIFT NEEDED IN THE PERMUTATION TO    .
    PUT THESE FACES IN CANONICAL FORM,  AND PRM[DELTA] CONTAINS THE    .
    NEIGHBORS EDGE-COUNTS IN CANONICAL FORM. THE LATTER MUST BE        .
    STUFFED INTO THE QLD OR QSD ARRAYS FOR COMPARISON WITH OTHERS. ;   .
    Q[Z] ← 0 & PRM[DELTA[Z]][1:5 :43] & DIM[44:44: 4]];                .
END;     COMMENT    END OF Z LOOP WHICH BEGAN AT STARTPRM.        ;    .
Y ← G;                                                                 .
SORT:          COMMENT                                       SORT:;    .
BOOL ← FALSE;                                                          .
FOR Z ← 2 STEP 1 UNTIL Y DO IF Q[Z] > Q[(X←Z-1)] THEN                  .
BEGIN DOUBLE (Q[Z], Q[X], ←, Q[X], Q[Z]);           ,                  .
   BOOL ← TRUE;                                                        .
END;                                                                   .
IF BOOL THEN BEGIN Y ← Y-1;     GO TO SORT;     END;                   .
IF CNIL = 0 THEN GO TO FILLQSD;COMMENT  SEE CANON: + 1       ;         .
FOR Z ← 1 STEP 1 UNTIL G DO QLD[LIXD,Z+LIXM] ← Q[Z];                   .
GO TO END5;                                                            .
FILLQSD:    COMMENT                                        FILLQSD;    .
FOR Z ← 1 STEP 1 UNTIL G DO QSD[SIXD,Z+SIXM] ← Q[Z];                   .
END5:                   COMMENT                             END5: ;    .
```

```
BEGIN LABEL C3, C4, C5, C6, C7, C8, C9, C10, COMPL, COMPS, D3, D4,     .
   D5, D6, D7, D8, D9, D10, DETAILL, DETAILS, END1,           END3,     .
   END4,         END7, M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, N1,     .
   N2, N3, N4, N5, N6, N7, N8, N9, N10, NEQL, NEQS, NEWL, NEWS,        .
   PACKFREQL, PACKFREQS, PRINTPOLY;                                     .
   SWITCH SW1 ← C4, C5, C6, C7, C8, C9, C10;                           .
   SWITCH SW3 ← D4, D5, D6, D7, D8, D8, D8;                            .
   SWITCH SW4 ← N3, N4, N5, N6, N7, N8, N9, N10;                       .
   SWITCH SW5 ← M3, M4, M5, M6, M7, M8, M9, M10;                       .
   IF BOOLIO THEN                                                      .
   BEGIN IF CNTL = 0 THEN GO TO DETAILS;                               .
      GO TO DETAILL;                                                   .
   END;                                                                .
   COMMENT  WE HAVE TWO SETS OF ARRAYS FOR THE POLYHEDRA FOUND THUS .
   FAR. WE HAVE ARBITRARILY SEPARATED THEM ACCORDING TO WHETHER THEY.
   HAVE ANY FACES OF EDGE-COUNT F OR F-L, OR NOT. WE HAVE TWO SETS   .
   OF PARALLEL CODE TO TREAT THESE TWO CLASSES OF POLYHEDRA, S AND   .
   L. THE LATTER BEGINS HERE.  FOR EACH STORED POLYHEDRON WE HAVE A .
   CODE WORD, FREQL[], SHOWING IN THE LOW-ORDER  4 BITS THE NUMBER   .
   OF TRIANGLES, IN THE NEXT 4 BITS THE NUMBER OF QUADRILATERALS,    .
   AND SO FORTH.  IF THE NEW POLYHEDRON FORMED BY THE PRESENT PARTI-.
   TION HAS A DIFFERENT TRIBE NUMBER FROM ALL THOSE POLYHEDRA FOUND .
   AND STORED THUS FAR,  THEN WE CAN BE SURE THAT THE NEW ONE IS NOT.
   ISOMORPHIC WITH ANY OF THE OLD ONES.  THUS WE CAN ADD THE NEW ONE.
   TO THE LIST WITHOUT FURTHER CHECKING.  ON THE OTHER HAND, IF WE  .
   DO FIND A MATCH OF FREQUENCY WORDS, WE STILL CANNOT BE SURE THAT .
   WE HAVE AN ISOMORPHIC POLYHEDRON BUT MUST NOW CHECK THE SO-CALLED.
   QLD[] WORDS (QSD[] FOR S POLYS), WHICH CONTAIN THE INFORMATION   .
   AS TO DEPLOYMENT OF FACES, BY DIMENSION,  IN THE POLYHEDRON.      .
   NOTE THAT MATCH[] CONTAINS THE SUBSCRIPTS OF STORED POLYHEDRA     .
   HAVING THE SAME FREQUENCY WORD AS THE NEW ONE BEING TESTED.       .
   MCH IS THE NUMBER OF SUCH MATCHES FOUND.    ;                     .
   MCH ← 0;                                                          .
   IF CNTL = 0 THEN GO TO COMPS;                                     ,
   COMPL: COMMENT                                          COMPL:;   .
   FOR Y ← 1 STEP 1 UNTIL ML DO                                      .
   BEGIN FREQ ← FREQL [Y DIV 700, Y MOD 700];                        .
      GO TO SW1 [F - 3]; COMMENT   C4, C5,....C10.     ;             .
      C10: IF COUNT [10] ≠ FREQ . [16 : 4] THEN GO TO END1;          .
      C9: IF COUNT [9] ≠ FREQ . [20 : 4] THEN GO TO END1;            .
      C8: IF COUNT [8] ≠ FREQ . [24 : 4] THEN GO TO END1;            .
      C7: IF COUNT [7] ≠ FREQ . [28 : 4] THEN GO TO END1;            .
      C6: IF COUNT [6] ≠ FREQ . [32 : 4] THEN GO TO END1;            .
      C5: IF COUNT [5] ≠ FREQ . [36 : 4] THEN GO TO END1;            .
      C4: IF COUNT [4] ≠ FREQ . [40 : 4] THEN GO TO END1;            .
      C3: IF COUNT [3] ≠ FREQ . [44 : 4] THEN GO TO END1;            .
      MCH ← MCH + 1;                                                 .
      MATCH [MCH] ← Y;                                               .
   END1:    END;  COMMENT  END OF Y LOOP.                  END1:;    .
   IF MCH = 0 THEN GO TO NEWL; COMMENT ADD NEW POLY TO THE LIST.  ; .
   COMMENT NOW OUR NEW POLYHEDRON IS DESIGNATED BY A LIST OF F+1 = G.
   WORDS, EACH WORD DESIGNATING ONE FACE, AND EACH WORD SHOWING THE .
   EDGE-COUNT OF THE FACE AND THE EDGE-COUNTS OF ITS NEIGHBORS, IN  .
   CANONICAL FORM.  NOW WE HAVE TO COMPARE THE NEW POLYHEDRON WITH   .
   THE SET OF POLYHEDRA HAVING THE SAME TRIBE NUMBER, AND ARRAYED    .
```

```
BY FACES IN QLD[MATCH[Z],Y] ISOLATED ABOVE.      SINCE, IN THE        .
COMPARISON OF QLD WORDS, REJECTION OF THE NEW POLYHEDRON OCCURS       .
UPON FINDING AN ISOMORPHISM, AND ISOMORPHISMS OCCUR MORE OFTEN        .
THAN NOT, IT IS BEST TO COMPARE THE NEW POLYHEDRON COMPLETELY         .
WITH THE FIRST POLYHEDRON IN STORAGE BEFORE PROCEEDING TO THE         .
NEXT, REJECTING THE NEW ONE IF IT IS MATCHED BY ANY POLYHEDRON IN.
STORAGE, AND ADDING IT TO THE COLLECTION OTHERWISE.   ;               .
DETAILL: COMMENT                              DETAILL:;               .
FOR Z ← 1 STEP 1 UNTIL MCH DO COMMENT    FOR EACH MATCH IN FREQ.;.
BEGIN W ← MATCH [Z] DIV 92;                                           .
   X ← (MATCH [Z] MOD 92) × 11;                                       .
  FOR Y ← 1 STEP 1 UNTIL G DO IF QLD[LIXD,Y+LIXM] ≠ QLD[W,Y+X]        .
     THEN GO TO END3;   COMMENT  SOME FACE NOT EQUAL.       ;         .
  GO TO ENDISC;                                                       .
END3:    END;   COMMENT   END OF Z LOOP.                  END3:;      .
IF BOOLIO THEN                                                        .
BEGIN FOR Z ← 1 STEP 1 UNTIL G DO DELTA [Z] ← DELSAVE [Z];           .
   GO TO NEWL;                                                        .
END;                                                                  .
COMMENT  IF WE COME OUT THE BOTTOM OF THE Z LOOP, WE HAVE CHECKED.
 ALL THE STORED POLYHEDRA AND HAVE NOT FOUND AN ISOMORPHISM. NOW      .
WE MUST TURN   THE NEW POLYHEDRON "INSIDE OUT" BY REVERSING THE       .
CYCLIC ORDER OF ITS     NABORS ,  AND THEN GO BACK AND CHECK IT       .
AGAIN FOR ISOMORPHISM.    ;                                           .
BOOLIO ← TRUE;                                                        .
GO TO STARTPRM;                                                       .
NEWL: COMMENT                                                  NEWL;.
ML ← ML + 1;                                                          .
COMMENT  ONE MORE POLY HAS BEEN ADDED TO THE OUTPUT LIST. ;           .
IF G = GMAX THEN GO TO PACKFREQL;                                     .
COMMENT  NO NEED TO MAKE QL ARRAY.    ;                               .
FOR Z ← 1 STEP 1 UNTIL G DO COMMENT     FOR EACH FACE.      ;         .
BEGIN DEL ← DELTA [Z];                                                .
   QL [ML, Z] ← DIM ← QAT [Z, 0];                                     .
   GO TO SW4 [DIM - 2];                                               .
   N10: QL [ML, Z] . [4 : 4] ← QAT [Z, (((DEL + 9) MOD DIM) +1)];.
   N9: QL [ML, Z] . [8 : 4] ← QAT [Z, (((DEL + 8) MOD DIM) + 1)];.
   N8: QL [ML, Z] . [12 : 4] ← QAT [Z, (((DEL + 7) MOD DIM) +1)];.
   N7: QL [ML, Z] . [16 : 4] ← QAT [Z, (((DEL + 6) MOD DIM) +1)];.
   N6: QL [ML, Z] . [20 : 4] ← QAT [Z, (((DEL + 5) MOD DIM) +1)];.
   N5: QL [ML, Z] . [24 : 4] ← QAT [Z, (((DEL + 4) MOD DIM) +1)];.
   N4: QL [ML, Z] . [28 : 4] ← QAT [Z, (((DEL + 3) MOD DIM) +1)];.
   N3: QL [ML, Z] . [32 : 4] ← QAT [Z, (((DEL + 2) MOD DIM) +1)];.
   N2: QL [ML, Z] . [36 : 4] ← QAT [Z, (((DEL + 1) MOD DIM) +1)];.
   N1: QL [ML, Z] . [40 : 4] ← QAT [Z, (DEL + 1)];                    .
END;                                                                  .
WRITE (QLDFIL, *, FOR Z ← 1 STEP 1 UNTIL G DO QL [ML, Z]);            .
PACKFREQL: COMMENT                                  PACKFREQL:;       .
FREQL[ML DIV 700, ML MOD 700] ←                                       .
     COUNT[3] & COUNT[4][40:44:4] & COUNT[5][36:44:4] &              .
     COUNT[6][32:44:4] & COUNT[7][28:44:4] & COUNT[8][24:44:4] & .
     COUNT[9][20:44:4] & COUNT[10][16:44:4]; COMMENT  TRIBE NO. ;.
IF F < 7 THEN GO TO PRINTPOLY;                                        .
WRITE (QLDFIL, *, FREQL [ML DIV 700, ML MOD 700], FOR Z ← 1           .
   STEP 1 UNTIL G DO QLD [LIXD, Z + LIXM]);                           .
```

```
GO TO PRINTPOLY;
COMPS: COMMENT                                                   COMPS:;
FOR Z ← 1 STEP 1 UNTIL MS DO
BEGIN FREQ ← FREQS [Z];
   GO TO SW3 [F - 3]; COMMENT D4, D5, ...D8, D8, D8.     ;
   D8: IF COUNT [8] ≠ FREQ . [24 : 4] THEN GO TO END4;
   D7: IF COUNT [7] ≠ FREQ . [28 : 4] THEN GO TO END4;
   D6: IF COUNT [6] ≠ FREQ . [32 : 4] THEN GO TO END4;
   D5: IF COUNT [5] ≠ FREQ . [36 : 4] THEN GO TO END4;
   D4: IF COUNT [4] ≠ FREQ . [40 : 4] THEN GO TO END4;
   D3: IF COUNT [3] ≠ FREQ . [44 : 4] THEN GO TO END4;
   MCH ← MCH + 1;
   MATCH [MCH] ← Z;
END4:  END;  COMMENT   END OF  Z LOOP.                        END4:  ;
IF MCH = 0 THEN GO TO NEWS;
DETAILS: COMMENT                                    DETAILS:;
FOR Z ← 1 STEP 1 UNTIL MCH DO COMMENT  FOR EACH MATCH IN FREQ. ;
BEGIN W ← MATCH [Z] DIV 92;
   X ← (MATCH [Z] MOD 92) × 11;
   FOR Y ← 1 STEP 1 UNTIL G DO
   IF QSO[SIXD,Y+SIXM] ≠ QSO[W,Y+X] THEN GO TO END7;
   GO TO ENDISO;
END7:    END;   COMMENT END OF Z LOOP.                          END7: ;
IF BOOLIO THEN
BEGIN FOR Z ← 1 STEP 1 UNTIL G DO DELTA [Z] ← DELSAVE [Z];
   GO TO NEWS;
END;
BOOLIO ← TRUE;
GO TO STARTPRM;
NEWS: COMMENT                                                     NEWS:;
MS ← MS + 1;
IF G = GMAX THEN GO TO PACKFREQS;
FOR Z ← 1 STEP 1 UNTIL G DO COMMENT    FOR EACH FACE.      ;
BEGIN DEL ← DELTA [Z];
   QS [MS, Z] ← DIM ← QAT [Z, 0];
   GO TO SW5 [DIM - 2];
   M10: QS [MS, Z] . [4 : 4] ← QAT [Z, (((DEL + 9) MOD DIM) +1)]];
   M9: QS [MS, Z] . [8 : 4] ← QAT [Z, (((DEL + 8) MOD DIM) + 1)]];
   M8: QS [MS, Z] . [12 : 4] ← QAT [Z, (((DEL + 7) MOD DIM) +1)]];
   M7: QS [MS, Z] . [16 : 4] ← QAT [Z, (((DEL + 6) MOD DIM) +1)]];
   M6: QS [MS, Z] . [20 : 4] ← QAT [Z, (((DEL + 5) MOD DIM) +1)]];
   M5: QS [MS, Z] . [24 : 4] ← QAT [Z, (((DEL + 4) MOD DIM) +1)]];
   M4: QS [MS, Z] . [28 : 4] ← QAT [Z, (((DEL + 3) MOD DIM) +1)]];
   M3: QS [MS, Z] . [32 : 4] ← QAT [Z, (((DEL + 2) MOD DIM) +1)]];
   M2: QS [MS, Z] . [36 : 4] ← QAT [Z, (((DEL + 1) MOD DIM) +1)]];
   M1: QS [MS, Z] . [40 : 4] ← QAT [Z, (DEL + 1)]];
END;
WRITE (QSOFIL, *, FOR Z ← 1 STEP 1 UNTIL G DO QS [MS, Z]);
PACKFREQS: COMMENT                                 PACKFREQS:;
      FREQS[MS] ←COUNT[3] & COUNT[4][40:44:4] & COUNT[5][36:44:4]
   & COUNT[6][32:44:4] & COUNT[7][28:44:4] & COUNT[8][24:44:4] ;
IF F < 7 THEN GO TO PRINTPOLY;
WRITE (QSOFIL, *, FREQS [MS], FOR Z ← 1 STEP 1 UNTIL G DO QSO [
   SIXD, Z + SIXM]);
PRINTPOLY: COMMENT                                 PRINTPOLY:;
```

```
        WRITE(LP[NU],FMT91, (MS + ML), FOR Z ← 1 STEP 1 UNTIL G DO       .
        [FOR Y ← QAT[Z,0] STEP -1 UNTIL 1 DO CHAR[QAT[Z,Y]], 48]));      .
        WRITE(LP,     FMT92, F, PMAX, I, MS, ML);                        .
        IF (MS + ML) MOD 50= 0 THEN WRITE (LP [PAGE]);                   .
     END;                                                                .
ENDISO: END; COMMENT END OF PROCEDURE ISOCHECK.              ENDISO:  ;  .
COMMENT ******************** EXECUTION ********************EXECUTION ;.
GMAX ← 11;                                                               .
T1 ← TIME(1);     COMMENT   START THE CLOCK.          ;                  .
FILL CHAR[*] WITH "0","1","2","3","4","5","6","7","8","9","A","B","C",   .
     "D","E","F" ;                                                       .
READ(F, PMAX, I, MS, ML); COMMENT  PUNCH THIS NEW DATA CARD TO RESTART.;.
COMMENT F = NUMBER OF FACES IN POLYHEDRON TO BE PARTITIONED.             .
        PMAX = MAX NUMBER OF INPUT POLYHEDRA, INDEXED ON I.              .
         MS AND ML ARE THE NUMBERS OF S AND L POLY STORED AWAY.    ;     .
P[0] ← 1;  P[1] ← 17187;  P[2] ← 13331;  P[3] ← 16915;  P[4] ← 8979;     .
IF MS + ML = 0 THEN GO TO GENESIS; COMMENT THIS IS NOT A RESTART.    ;   .
WRITE(LP[DBL], FMT16, F, PMAX, I, MS, ML);                               .
SPACE (PFIL, I-1); COMMENT PREPARE TO READ THE ITH INPUT POLYHEDRON.   ;.
IF F+1 < GMAX THEN GO TO READALL; COMMENT QL AND QS ARE ALSO ON TAPE.  ;.
IF MS = 0 THEN GO TO MSZERO;                                             .
FOR Z ← 1 STEP 1 UNTIL MS-1 DO                                           .
BEGIN W ← Z DIV 92;                                                      .
     X ← (Z MOD 92) × 11;                                                .
     READ (QSDFIL, 12, INQ [*]);                                         .
     FREQS [Z] ← INQ [0];                                                .
     FOR Y ← 1 STEP 1 UNTIL 11 DO QSD [W, Y + X] ← INQ [Y];              .
END;                                                                     .
Z ← MS;                                                                  .
W ← Z DIV 92;                                                            .
X ← (Z MOD 92) × 11;                                                     .
READ(QSDFIL[NO],12,INQ[*]);                                              .
FREQS[Z] ← INQ[0];                                                       .
FOR Y ← 1 STEP 1 UNTIL 11 DO QSD[W, Y+X] ← INQ[Y];                       .
WRITE(QSDFIL, 12, INQ[*]);                                               .
MSZERO:                      COMMENT                            MSZERO:;.
IF ML = 0 THEN GO TO MLZERO;                                             .
FOR Z ← 1 STEP 1 UNTIL ML-1 DO                                           .
BEGIN W ← Z DIV 92;                                                      .
     X ← (Z MOD 92) × 11;                                                .
     READ (QLDFIL, 12, INQ [*]);                                         .
     FREQL [Z DIV 700, Z MOD 700] ← INQ [0];                             .
     FOR Y ← 1 STEP 1 UNTIL 11 DO QLD [W, Y + X] ← INQ [Y];              .
END;                                                                     .
Z ← ML;                                                                  .
W ← Z DIV 92;                                                            .
X ← (Z MOD 92) × 11;                                                     .
READ(QLDFIL[NO],12,INQ[*]);                                              .
FREQL[Z DIV 700, Z MOD 700] ← INQ[0];                                    .
FOR Y ← 1 STEP 1 UNTIL 11 DO QLD[W, Y+X] ← INQ[Y];                       .
WRITE(QLDFIL, 12, INQ[*]);                                               .
MLZERO:                      COMMENT                            MLZERO:;.
FOR Z ← 1 STEP 1 UNTIL MS DO                                             .
BEGIN W ← Z DIV 92;                                                      .
     X ← (Z MOD 92) × 11;                                                .
```

```
    WRITE (LP, FMT11, Z, FOR Y ← 1 STEP 1 UNTIL 11 DO QSD [W, Y + X]);     .
END;                                                                      .
FOR Z ← 1 STEP 1 UNTIL ML DO                                              .
BEGIN W ← Z DIV 92;                                                       .
    X ← (Z MOD 92) × 11;                                                  .
    WRITE (LP, FMT10, Z, FOR Y ← 1 STEP 1 UNTIL 11 DO QLD [W, Y + X]);     .
END;                                                                      .
WRITE(LP[PAGE]);                                                          .
GO TO RESTART;                                                            .
READALL:                    COMMENT                             READALL: ;.
IF MS = 0 THEN GO TO MSMT;                                                .
FOR Z ← 1 STEP 1 UNTIL MS-1 DO                                            .
BEGIN W ← Z DIV 92;                                                       .
    X ← (Z MOD 92) × 11;                                                  .
    READ (QSDFIL, *, FOR Y ← 1 STEP 1 UNTIL F + 1 DO QS [Z, Y]);           .
    READ (QSDFIL, *, FREQS [Z], FOR Y ← 1 STEP 1 UNTIL F + 1 DO QSD [W    .
    , Y + X]);                                                            .
END;                                                                      .
Z←MS;                                                                     .
W ← Z DIV 92;                                                             .
X ← (Z MOD 92) × 11;                                                      .
READ(QSDFIL,       *,           FOR Y ← 1 STEP 1 UNTIL F+1 DO QS[Z,Y]);    .
READ(QSDFIL[NO], *, FREQS[Z], FOR Y ← 1 STEP 1 UNTIL F+1 DO QSD[W,Y+X]);.
WRITE(QSDFIL    , *, FREQS[Z], FOR Y ← 1 STEP 1 UNTIL F+1 DO QSD[W,Y+X]);.
MSMT:                       COMMENT                                MSMT: ;.
IF ML = 0 THEN GO TO MLMT;                                                .
FOR Z ← 1 STEP 1 UNTIL ML-1 DO                                            .
BEGIN W ← Z DIV 92;                                                       .
    X ← (Z MOD 92) × 11;                                                  .
    READ (QLDFIL, *, FOR Y ← 1 STEP 1 UNTIL F + 1 DO QL [Z, Y]);           .
    READ (QLDFIL, *, FREQL [Z DIV 700, Z MOD 700], FOR Y ← 1 STEP 1       .
       UNTIL F + 1 DO QLD [W, Y + X]);                                    .
END;                                                                      .
Z←ML;                                                                     .
W ← Z DIV 92;                                                             .
X ← (Z MOD 92) × 11;                                                      .
READ (QLDFIL, *, FOR Y ← 1 STEP 1 UNTIL F + 1 DO QL [Z, Y]);               .
READ(QLDFIL[NO], *, FREQL[Z DIV 700, Z MOD 700],                          .
   FOR Y ← 1 STEP 1 UNTIL F+1 DO QLD[W,Y+X]);                             .
WRITE(QLDFIL    , *, FREQL[Z DIV 700, Z MOD 700],                         .
   FOR Y ← 1 STEP 1 UNTIL F+1 DO QLD[W,Y+X]);                             .
MLMT:                       COMMENT                                MLMT: ;.
GO TO RESTART;                                                            .
GENESIS:                COMMENT                                 GENESIS: ;.
WRITE(PFIL, *, FOR J ← 0 STEP 1 UNTIL 4 DO P[J], 8888888);                .
REWIND(PFIL);                                                             .
START:                 COMMENT                                     START:;.
WRITE(LP[PAGE]);   COMMENT SKIP TO THE NEXT PAGE.   ;                     .
RESTART:                  COMMENT                                RESTART;.
G ← F + 1   ;  COMMENT NEW POLYHEDRON WILL HAVE G FACES.    ;             .
WRITE(LP[PAGE], FMT4, F+1, F); COMMENT WRITE STARTING MESSAGE;            .
ILOOP:                       COMMENT                              ILOOP:;.
READ(PFIL, *, FOR Y ← 0 STEP 1 UNTIL F DO P[Y]);  COMMENT I IS IN P[0].;.
IF P[0] = I THEN GO TO POK; COMMENT WE GOT THE RIGHT INPUT POLYHEDRON. ;.
WRITE (LP, FMT17, I, P[0]);  COMMENT  WE DID NOT.    ;                    .
```

```
GO TO FINALEND;                                                              .
POK:                          COMMENT                                   POK;.
FOR J ← 1 STEP 1 UNTIL F  DO   COMMENT   FOR EACH FACE.   ;                  .
BEGIN PAT[J,0] ← P[J].[44:4];                                                .
    GO TO SW6 [PAT [J, 0]];                                                  .
    B10: PAT [J, 10] ← P [J] . [4 : 4];                                      .
    B9: PAT [J, 9] ← P [J] . [8 : 4];                                        .
    B8: PAT [J, 8] ← P [J] . [12 : 4];                                       .
    B7: PAT [J, 7] ← P [J] . [16 : 4];                                       .
    B6: PAT [J, 6] ← P [J] . [20 : 4];                                       .
    B5: PAT [J, 5] ← P [J] . [24 : 4];                                       .
    B4: PAT [J, 4] ← P [J] . [28 : 4];                                       .
    B3: PAT [J, 3] ← P [J] . [32 : 4];                                       .
    B2: PAT [J, 2] ← P [J] . [36 : 4];                                       .
    B1: PAT [J, 1] ← P [J] . [40 : 4];                                       .
END;   COMMENT   END OF J LOOP.   ;                                          .
COMMENT  NOW THE POLYHEDRON NUMBER I IS DECOMPOSED INTO ATOMIC ELEMENTS,.
 PAT[J,K], FOR K = 0, 1, ...,PAT[J,0].  THE DIMENSION OF THE FACE IS IN  .
PAT[J,0] AND THE KTH NABOR IS IN PAT[J,K].   ;                               .
COMMENT  FOR EACH FACE, INDEXED ON J, DO THE FOLLOWING VERY BIG LOOP.  ;.
FOR J ← 1 STEP 1 UNTIL F DO                                                  .
BEGIN N ← PAT[J,0]; COMMENT FACE J HAS N EDGES.   ;                          .
    VMAX ← N DIV 2;                                                          .
    COMMENT   VMAX = MAX NUMBER OF VERTICES TO BE CUT OFF.  ;                .
    FOR Z ← 1 STEP 1 UNTIL VMAX DO PAT [J, Z + N] ← PAT [J, Z];              .
    VM ← VMAX - 1;                                                           .
    FOR V ← 1 STEP 1 UNTIL VM DO FOR S ← 1 STEP 1 UNTIL N DO                 .
    BEGIN PARTITION;                                                         .
       ISOCHECK;                                                             .
    END;                                                                     .
    IF N MOD 2 = 0 THEN SAM ← VMAX ELSE SAM ← N;                             .
    COMMENT   SOME PARTITIONS CAN BE AVOIDED WHEN V = N/2.    ;              .
    V ← VMAX;                                                                .
    FOR S ← 1 STEP 1 UNTIL SAM DO                                            .
    BEGIN PARTITION;                                                         .
       ISOCHECK;                                                             .
    END;                                                                     .
    COMMENT  END 2ND S LOOP. ALL CUTS DONE. ;                                .
END;    COMMENT  END OF J LOOP.  ALL FACES OF POLY I HAVE BEEN CUT.   ;.
I ← I + 1;  COMMENT  CUT UP NEXT POLYHEDRON.    ;                            .
IF I ≤ PMAX THEN GO TO ILOOP;                                                .
WRITE(LP[PAGE]);                                                             .
FOR Z ← 1 STEP 1 UNTIL MS DO                                                 .
BEGIN W ← Z DIV 92;                                                          .
      X ← (Z MOD 92)×11;                                                     .
      WRITE(LP,FMT11, Z, FOR Y ← 1 STEP 1 UNTIL 11 DO,QSO[W,Y+X]);           .
END;                                                                         .
WRITE(LP[PAGE]);                                                             .
FOR Z ← 1 STEP 1 UNTIL ML DO                                                 .
BEGIN W ← Z DIV 92;                                                          .
      X ← (Z MOD 92)×11;                                                     .
      WRITE(LP,FMT10, Z, FOR Y ← 1 STEP 1 UNTIL 11 DO QLO[W,Y+X]);           .
END;                                                                         .
IF G = GMAX THEN GO TO FINALEND;  COMMENT GMAX IS ASSIGNED FIRST.    ;       .
REWIND(PFIL);                                                                .
```

```
FOR Z ← 1 STEP 1 UNTIL MS DO                                                              .
     WRITE(PFIL, *, Z, FOR Y ← 1 STEP 1 UNTIL G DO QS[Z,Y]);                              .
FOR Z ← 1 STEP 1 UNTIL ML DO                                                              .
     WRITE(PFIL, *, Z+MS, FOR Y ← 1 STEP 1 UNTIL G DO QL[Z,Y]);                           .
WRITE(PFIL, *, 8888888);                                                                  .
REWIND(PFIL);                                                                             .
F ← G;  COMMENT INPUT POLYHEDRA ARE NOW G-FACED.       ;                                  .
PMAX ← MS + ML;   COMMENT THE NUMBER OF INPUT POLYHEDRA IS ML+MS.    ;                    .
I ← 1;   COMMENT   START CUTTING THE FIRST INPUT POLYHEDRON.    ;                         .
ML ← MS ← 0;   COMMENT   INITIALIZE MAX INDICES ON STORED RESULTS.        ;.
WRITE(QSUFIL, *, F);  WRITE(QLUFIL, *, F);                                                .
REWIND(QSUFIL);                                                                           .
REWIND(QLUFIL);                                                                           .
GO TO START;  COMMENT   SO NOW WE GO BACK AND CUT UP THESE POLYHEDRA.  ;.
FINALEND:      COMMENT   END OF ENTIRE PROGRAM.                      FINALEND:;.
WRITE(LP[DBL],FMT15, (TIME(1) - T1) / 3600); COMMENT TIME IN MINUTES.  ;.
END.                                                                                      .
```

LIST OF POLYHEDRA

TRI-LINEAR POLYHEDRA

OF

5 THROUGH 8 FACES

```
1 4352 3415 4251 231 321
```

```
1 43562 53416 4251 231 3261 521
2 4652 5341 4256 2361 3216 4351
```

```
1 435672 653417 4251 312 6132 5271 621
2 435762 65341 4251 312 67132 5217 561
3 437562 65341 42571 312 61732 521 351
4 43762 65341 42571 312 6732 5217 3561
5 43567 65347 4251 3172 6132 5271 6241
```

```
 1 4356782 7653418 4251 312 6132 7152 6281 721
 2 4356872 765341 4251 312 6132 78152 6218 671
 3 4358672 765341 4251 312 68132 71852 621 561
 4 435872 765341 4251 312 68132 7852 6218 5671
 5 438672 765341 42581 312 6832 71852 621 3561
 6 435678 765348 4251 3182 6132 7152 6281 7241
 7 43582 7653418 4251 312 68132 7852 628 56721
 8 43872 765341 42581 312 6832 7852 6218 35671
 9 435862 41653 4251 312 781326 75218 685 5761
10 43862 41653 42581 312 78326 75218 685 35761
11 48762 41653 4258 3812 78326 7521 6185 43571
12 435762 416583 42851 312 713826 7521 615 532
13 435762 41683 42851 312 71386 75821 615 6532
14 437562 658341 428571 231 738261 521 351 532
```

TRI-LINEAR POLYHEDRA

OF

9 FACES

1	438692	419653	42581	312	78326	752918	685	76135	621
2	493862	41653	425819	3912	78326	75218	685	76135	431
3	43892	419653	42581	312	78326	75298	685	769135	8621
4	49862	41653	42589	3912	78326	75218	685	761935	4381
5	762498	34165	4258	38912	67832	7521	6185	435719	481
6	76298	349165	4258	3892	67832	7521	6185	435719	2481
7	76948	34965	4258	38192	67832	75291	6185	43571	6241
8	79248	341965	4258	3812	67832	7529	69185	43571	7621
9	43567892	87653419	4251	312	6132	7152	8162	7291	821
10	43567982	8765341	4251	312	6132	7152	89162	7219	781
11	43569782	8765341	4251	312	6132	79152	81962	721	671
12	43596782	8765341	4251	312	69132	71952	8162	721	561
13	4356982	8765341	4251	312	6132	79152	8962	7219	6781
14	4359782	8765341	4251	312	69132	7952	81962	721	5671
15	4356789	8765349	4251	3192	6132	7152	8162	7291	8241
16	435692	87653419	4251	312	6132	79152	8962	729	67821
17	435982	8765341	4251	312	69132	7952	8962	7219	56781
18	439782	8765341	42591	312	6932	7952	81962	721	35671
19	356789	8765349	42519	392	6132	7152	8162	7291	82431
20	43569872	417653	4251	312	3261	891527	8621	7196	681
21	43596872	417653	4251	312	32691	819527	8621	716	561
22	43956872	417653	42591	312	32619	81527	8621	716	351
23	49356872	417653	42519	3912	3261	81527	8621	716	431
24	4356972	417653	4251	312	3261	891527	86219	796	6871
25	4396872	417653	42591	312	3269	819527	8621	716	3561
26	4956872	417653	4259	3912	32619	81527	8621	716	4351
27	3568729	4917653	42519	392	3261	81527	8621	716	2431
28	496872	417653	4259	3912	3269	819527	8621	716	43561
29	568729	4917653	4259	392	32619	81527	8621	716	24351
30	4356872	4176593	42951	312	39261	81527	8621	716	532
31	4356872	4176953	4251	312	32961	815927	8621	716	652
32	4356872	4179653	4251	312	3261	815297	86921	716	762
33	4356872	417953	4251	312	32961	81597	86921	716	7652
34	4356872	41793	42951	312	3961	81597	86921	716	76532
35	43568792	41953	4251	312	32961	81597	8691	716	17652
36	43589672	765341	4251	312	81326	852719	621	5691	861
37	43958672	765341	42591	312	819326	85271	621	561	351
38	4359672	765341	4251	312	891326	852719	621	569	5861
39	4958672	765341	4259	3912	819326	85271	621	561	4351
40	435972	765341	4251	312	891326	85279	6219	569	58671
41	586729	7653491	4259	392	819326	85271	621	561	24351
42	435869	765349	4251	3192	81326	852791	629	561	67241
43	4358672	7659341	42951	312	813926	85271	621	561	532
44	4358672	7695341	4251	312	813296	859271	621	561	652
45	4358672	769341	42951	312	81396	859271	621	561	6532
46	495872	417653	4259	3912	681932	7852	8621	6715	4351
47	439672	765341	425891	312	8326	719852	621	5693	3861
48	435982	7653418	4251	312	689132	7852	628	721956	581
49	435829	765918	4951	319	681392	7852	628	72156	53412
50	769435	83965	492851	319	826713	75291	615	325	34162

TRI-LINEAR POLYHEDRA

OF

10 FACES

1	43869A2	41A9653	42581	312	78326	752918	856	76135	62A1	921
2	4386A92	419653	42581	312	78326	7529A18	856	76135	621A	691
3	438A692	419653	42581	312	78326	75291A8	856	76A135	621	861
4	43A8692	419653	4258A1	312	78326	752918	856	761A35	621	381
5	4A38692	419653	42581A	3A12	78326	752918	856	76135	621	431
6	438692A	4A19653	42581	31A2	78326	752918	856	76135	621	241
7	438A92	419653	42581	312	78326	7529A8	856	76A135	621A	8691
8	43A692	419653	4258A1	312	78326	75291A8	856	76A35	621	3861
9	4A8692	419653	4258A	3A12	78326	752918	856	761A35	621	4381
10	43869A	4A9653	42581	31A2	78326	752918	856	76135	62A1	9241
11	438A2	41A9653	42581	312	78326	7529A8	856	76A135	62A	86921
12	43A92	419653	4258A1	312	78326	7529A8	856	76A35	621A	38691
13	4A692	419653	4258A	3A12	78326	75291A8	856	76A35	621	43861
14	438692	419653	425A81	312	78A326	752918	856	7613A5	621	583
15	43A8692	419653	425A1	312	78A326	752918	856	761A5	621	5813
16	438692	419653	42581	312	7A8326	752918	8A56	76135A	621	785
17	438692	419653	42581	312	78326A	7A52918	85A6	76135	621	675
18	438692	419653	425A81	312	7A326	752918	8A56	7613A	621	7835
19	438692	4196A53	42581	312	7832A	7A2918	85A6	76135	621	2675
20	438A92	419A653	42581	312	78326	752A8	856	76A135	A21	29186
21	438692	419A53	42581	312	7832A	7A918	85A6	76135	6A21	75296
22	93862A4	4A1653	942581	91A23	78326	75218	685	76135	431	241
23	9A38624	41653	942581A	9123	78326	75218	685	76135	43A1	931
24	938624A	41653	942581	9A123	78326	75218	685	76135	431A	491
25	938A24	41A653	942581	9123	78326	752A8	685	76A135	431	8621
26	93A624	41653	94258A1	9123	78326	7521A8	685	76A35	431	3861
27	93862A	4A1653	942581	9A23	78326	75218	685	76135	431A	2491
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30	938624	416A3	942A581	9123	783A6	75A218	685	76135	431	6532
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32	938624	41653	942581	9123	78326A	7A5218	685A	76135	431	675
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35	438A2	41A9653	42581	312	78326	75298	568	769A135	A862	8921
36	4A892	419653	4258A	3A12	78326	75298	568	7691A35	1862	4381
37	43892	4196A3	42A581	312	783A6	75A298	568	769135	1862	6532
38	43892	41965A	4A581	312A	783A26	75298	568	769135	1862	5342
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47	98A7624	65341	4258	91238	67832	7521	61A85	94357A1	481	871
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67 8A72496 534176 5942 3912 3269 819527 8621A 7A16 43561 871
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83 869A435 765349 4251 31A92 81326 852791 962 561 724A16 941
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87 49587A2 341A765 9425 3912 681932 7852 862A1 6715 4351 721
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91 43582A9 7659A18 4951 319 681392 7852 628 72156 41A253 291
92 435A829 765918 4951 319 68A1392 7852 628 721A56 41253 581
93 43A5829 765918 495A1 319 681A392 7852 628 72156 41253 351
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153	43569782	876A5341	4251	312	32A61	915A27	96281	721	671	652
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156	43569782	8A65341	4251	312	3261	9152A7	96A81	7A21	671	8762
157	43569782A	8765A1	4A51	31A	3A261	91527	96281	721	671	53412
158	43569782	876A41	4A51	312A	3A61	915A27	96281	721	671	65342
159	43569782	87A341	42A51	312	3A61	915A7	96A281	721	671	76532
160	43569782	8A5341	4251	312	32A61	915A7	96A81	7A21	671	87652
161	4356978A2	65341A	4251	312	3261	9152A7	96A81	7A1	671	18762
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173	56982A	4A187653	425A	3A2	3261A	79152	8962	9721	7816	24351
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175	4356A92	87653419	4251	312	3261	79A152	8962	729	821A67	691
176	4356A2	8765341A9	4251	312	3261	79A152	8962	729	82A67	6921
177	435A2	8765341A9	4251	312	326A1	79A52	8962	729	82A67	56921
178	4356A872	417653	4251	312	3261	9A15278	8621	9671A	8A6	6981
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194	43596872	4176A53	4251	312	9132A6	95A2781	8621	716	561	652
195	43596872	417A653	4251	312	91326	952A781	86A21	716	561	762
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206	8724A356	765341	94251A	9A123	3261	81527	8621	716	43A	4931
207	87249356	7653A41	94A251	912A3	3261	81527	8621	716	431	342
208	87249356	765A341	942A51	9123	3A261	81527	8621	716	431	532
209	87249356	765A41	94A51	912A3	3A261	81527	8621	716	431	5342
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213	872A396	4A17653	42591A	3A2	9326	819527	8621	716	5613	2431
214	8724396	4176A53	42591	312	932A6	8195A27	8621	716	5613	652
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216	8724956	34176A5	9425	3912	932A61	815A27	8621	716	4351	652
217	8724956	3417A65	9425	3912	93261	8152A7	86A21	716	4351	762
218	8729A56	4917653	4259	392	3261A9	81527	8621	716	435A12	951
219	872A956	49A17653	4259	392	32619	81527	8621	716	4351A2	291
220	872956	4917A653	4259	392	32619	8152A7	86A21	716	43512	762
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222	4356872	953417 6A	4251	312	96132	9A27815	8621	716	52A6	692
223	4356872	534176A	4251	312	96132A	9A27815	8621	716	5A6	6952
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225	43589672	765A341	42A51	312	3A2681	985271	621	9156	861	532
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1166 435A69782 87B341 42B51 312 A13B6 A5B791 96B281 721 716 561 76532
1167 43A56B782 8765341 425A1 312 A3261 9B1527 962818 721 67B 351 6971
1168 43A569782 8765B341 42B5A1 312 A3B261 91527 96281 721 671 351 532
1169 43A569782 876B5341 425A1 312 A32B61 915B27 96281 721 671 351 652
1170 43A569782 8765B41 4B5A1 312B A3B261 91527 96281 721 671 351 5342
1171 43A569782 876B341 42B5A1 312 A3B61 915B27 96281 721 671 351 6532
1172 43A569782B 8765B1 4B5A1 31B A3B261 91527 96281 721 671 351 53412
1173 4356A782B 8765B1 4B51 31B 3B261 9A1527 96281A 721 A67 9716 53412
1174 4356A78B2 65341B 4251 312 3261 9A152B7 96B81A 7B1 A67 9716 18762
1175 9782B4A56 8765B1 A4B5 3A1B A3B261 91527 96281 721 671 4351 53412
1176 9782B56 876534AB1 425A 3A2 32618A 91527 96281 721 671 435B2 2A51
1177 9782B6 876534AB1 425A 3A2 326BA 91B527 96281 721 671 435B2 2A561
1178 9782A56 8765B34A1 42B5A 3A2 3B261A 91527 96281 721 671 43512 532
1179 9782A56 876B534A1 425A 3A2 32B61A 915B27 96281 721 671 43512 652
1180 9782A56 87B6534A1 425A 3A2 3261A 9152B7 96B281 721 671 43512 762
1181 4356B2 8765341BA 4251 312 3261 9AB1527 8A962 72A 7A6 9782B6 6A21
1182 4356A2 8765B341A 42B51 312 3B261 9A1527 8A962 72A 7A6 978216 532
1183 4356A2 876B5341A 4251 312 32B61 9A15B27 8A962 72A 7A6 978216 652
1184 4356A2 87B65341A 4251 312 3261 9A152B7 8A96B2 72A 7A6 978216 762
1185 43569782 AB5341876 4251 312 A6132B 915A27 96281 721 716 5B26 A52
1186 43569782 A534187 6B 4251 312 A6132 915AB27 96281 721 716 52B6 6A2
1187 435697B82 A5341B6 4251 312 A6132 915A2B7 96B81 7B1 716 526 18762
1188 43569782B A5B1876 4B51 31B A613B2 915A27 96281 721 716 526 53412
1189 43569782B AB1876 4B51 31B A613B 915A27 96281 721 716 5B26 A53412
1190 43569782B 87A5B1 4B51 31B A613B2 915A7 96A281 721 671 6527 53412
1191 43569782A 8765BA1 4A51 31A 3AB261 91527 96281 721 671 412B53 5A2
1192 4356978A2 41AB653 4251 312 3261 9152BA7 96A81 7A1 716 876B21 A62
1193 4359BA6782 8765341 4251 312 32691 A95271 8162 721 AB156 961B 9A1
1194 435B9A6782 8765341 4251 312 3269B1 A95271 8162 721 A1B56 961 591
1195 4359A6B82 8765341 4251 312 32691 A9527B1 8B62 721B A156 961 6781
1196 4359B6782 8765341 4251 312 32691 A952718 8162 721 AB156 96B 9A61
1197 435BA6782 8765341 4251 312 3269B1 A95271 8162 721 AB56 961B 59A1
1198 4B59A6782 8765341 425B 3B12 3269 1B A95271 8162 721 A156 961 4351
1199 4359A6782 876B5341 4251 312 32B691 A95B271 8162 721 A156 961 652
1200 4359A6782 87B5341 4251 312 32B691 A95B71 816B2 721 A156 961 7652

1201 4359A6782B 8765B1 4B51 31B 3B2691 A95271 8162 721 A156 961 53412
1202 4359A6782 8765341 4251 312 326B91 A9B5271 8162 721 A15B6 961 695
1203 43596A82B 18765B 4B51 31B 913B26 9527A1 8A62 A721 561 7816 53412
1204 435A6782B 8765B1 4B51 31B 9A13B26 95271A 8162 721 A56 9615 53412
1205 435962 8765341BA 4251 312 91326 9527AB1 8A62 72A 561 82B67 6A21
1206 43592 8765341BA 4251 312 91326 9527AB 8A62 72A 56B1 82B67 96A21
1207 596A2B 876534B1A 425B 3B2 91B326 9527A1 8A62 72A 561 82167 24351
1208 43596A2 876B5341A 4251 312 9132B6 95B27A1 8A62 72A 561 82167 652
1209 4359A2 876B5341A 4251 312 9132B6 95B27A 8A62 72A 56A1 821967 652
1210 43596782A 8765BA1 4A51 31A 913AB26 95271 8162 721 615 412B53 5A2
1211 43596782BA 876B1 4A51 31A 913AB6 95B271 8162 721 615 41B53 65A12
1212 43562 87653418 9 4251 312 3261 AB15279 8962 729 A6782B 69B 6A921
1213 56A92B 876534B19 425B 3B2 3261B A15279 8962 729 A67821 691 24351
1214 4356A92 87653419B 4251 312 3261 A1527B9 8B62 72B A6B21 691 67829
1215 98724356 A53417B6 4251 312 A6132 A2B78915 86B21 9671 816 526 762
1216 98724356 A534176B 4251 312 A6132 AB278915 8621 9671 816 52B6 6A2
1217 435A96B72 417653 4251 312 A13269 8B19527 8621B 7B6 A561 915 6871
1218 435A96872 41765B3 42B51 312 A13B269 819527 8621 716 A561 915 532
1219 435A96872 4176B53 4251 312 A132B69 8195B27 8621 716 A561 915 652
1220 87243BA596 417653 425AB1 312 A32691 952781 8621 716 561 351B 3A1
1221 8724B3A596 417653 425A1B 3B12 A32691 952781 8621 716 561 351 431
1222 87243A5B6 417653 425A1 312 A3269B1 952781B 8621 716 56B 351 5961
1223 87243B596 417653 425AB1 312 A32691B 952781 8621 716 561 35B 3A51
1224 872B3A596 4B17653 425A1B 3B2 A32691 952781 8621 716 561 351 2431
1225 7243A596B 417653 425A1 312 A32691 95278B1 8621B 7B6 561 351 6871
1226 87243A596 41765B3 42B5A1 312 A3B2691 952781 8621 716 561 351 532
1227 87243A596 4176B53 425A1 312 A32B691 95B2781 8621 716 561 351 652
1228 87243A596 417B653 425A1 312 A32691 952B781 86B21 716 561 351 762
1229 8724A35B6 765341 A4251 A123 9B1326 952781B 8621 716 56B 431 5961
1230 8724B3596 765341 A4251B AB123 91326 952781 8621 716 561 43B 4A31
1231 724A3596B 765341 A4251 A123 91326 95278B1 8621B 7B6 561 431 6871
1232 8724A3596 7653B41 A4B251 A12B3 91326 952781 8621 716 561 431 342
1233 8724A3596 765B341 A42B51 A123 913B26 952781 8621 716 561 431 532
1234 8724A3596 76B5341 A4251 A123 9132B6 95B2781 8621 716 561 431 652
1235 8724A3596 7B65341 A4251 A123 91326 952B781 86B21 716 561 431 762
1236 8724A3596 765B41 A4B51 A12B3 913B26 952781 8621 716 561 431 5342
1237 43596A7B2 41B53 4251 312 9132B6 8A195B7 86B1A A67 561 8716 17652
1238 87B2435A6 41B53 4251 312 9A132B6 95B781A 86B1 716 A56 9615 17652
1239 872A3596 4A1765B3 42B51A A23 913B26 952781 8621 716 561 4312 532
1240 87B2A3596 4A1B53 4251A A23 9132B6 95B781 86B1 716 561 4312 17652
1241 87B243596 A341B5 A5142 312 A2B6913 95B781 86B1 716 561 325 17652
1242 43596872 A53417B6 4251 312 A69132 95A2B781 86B21 716 561 526 762
1243 43596872 A534176B 4251 312 A69132 95AB2781 8621 716 561 52B6 6A2
1244 43596872B A5B176 4B51 31B A6913B2 95A2781 8621 716 561 526 53412
1245 43596872B A65B17 4B51 31B 913B26 A781952 86A21 716 561 762 53412
1246 87A243596 41AB53 4251 312 9132BA6 95A781 86A1 716 561 765B21 A52
1247 872A3956 4A176B53 42591A A23 932B61 815B27 8621 716 513 4312 652
1248 87249356 A3417 6B5 942A51 9123 A2B613 815B27 8621 716 431 532 652
1249 86724395 76B5A341 42A591 312 93A2B681 85B271 621 615 351 325 652

TRI-LINEAR POLYHEDRA

OF

8 AND 9 FACES

WITH

MEC ≤ 6

1	46782	534187	4256	1236	3276	43571	81652	721
2	4682	534187	4256	1236	3276	435781	8652	6721
3	4872	53417	4256	81236	3276	43578	18652	4671
4	724685	75341	6425	3612	718632	43581	521	651
5	724865	75341	6425	36812	71632	43518	521	461
6	782465	753418	6425	3612	71632	4351	5281	721
7	72465	75341	68425	38612	71632	48351	521	643
8	435862	41653	4251	312	781326	75218	685	5761
9	435762	416583	42851	312	713826	7521	615	532
10	437562	658341	428571	231	738261	521	351	532

1	4982	534187	4256	91236	3276	435789	8652	19672	4681
2	4689	53497	4256	19236	3276	435781	86529	1679	41872
3	87294	534917	5642	819236	3276	35784	18652	1467	241
4	89724	53417	5642	81236	3276	35784	198652	91467	871
5	87294	53917	56492	81936	3276	35784	18652	1467	3412
6	824697	875341	5642	3612	3276	435791	819652	172	671
7	824967	875341	5642	36912	3276	435719	81652	172	461
8	824679	875341	5642	3612	3276	43571	891652	1972	781
9	82467	875341	56942	39612	3276	493571	81652	172	643
10	724685	753941	49256	36129	863271	81435	215	651	342
11	724965	75341	6425	891236	71632	843519	521	469	4861
12	724865	753941	64925	812936	71632	84351	521	461	342
13	824659	875341	6425	3612	632791	4351	8952	7219	5781
14	824657	875341	69425	39612	63271	49351	8152	721	643
15	358629	491653	42519	392	781326	75218	856	7615	2431

TRI-LINEAR POLYHEDRA

OF

10 FACES

WITH

MEC ≤ 6

1	9A824	753418	5642	91236	3276	357894	5286	1A9672	A1468	981
2	98A4	7534A8	5642	91A236	3276	357894	5286	A19672	1468	8241
3	982A4	753A18	564A2	91A36	3276	357894	5286	19672	1468	3412
4	9824	75A418	564A	912A36	3A276	357894	5286	19672	1468	5342
5	9824	7A3418	5642A	91236	3A76	357894	5A286	19672	1468	7532
6	98A4	753A8	564A2	91A36	3276	357894	5286	19672A	1468	34182
7	982A4	75A18	564A	91A36	3A276	357894	5286	19672	1468	53412
8	89A46	53497	5642	1A9236	3276	814357	52986	1679	A18724	941
9	8A946	53497	5642	19236	3276	814357	52986	A1679	1A8724	891
10	8946	5349A7	5642	19236	3276	814357	52A986	1679	187A24	972
11	894A6	53497	5A42	1923A	3276A	81A57	52986	1679	18724	14356
12	9487A2	5391A7	92564	81936	3276	57843	8652A1	1467	3412	721
13	948A72	53917	92564	81936	3276	57843	86521A	A1467	3412	871
14	94A872	53917	92564	8A1936	3276	57843	86521	1A467	3412	481
15	982465	875341	6A425	3A612	632791	4A351	8952	9721	7815	643
16	948A72	917534	5642	923681	3276	35784	86521A	67A14	124	871
17	94872	917534	5A642	923681	A3276	3A5784	86521	6714	124	563
18	94872	917534	5642	923681	327A6	35A784	86A521	6714	124	765
19	94872	917534	5642	923681	3276	357A84	8A6521	6A714	124	786
20	9724A8	53417	5642	368A12	3276	35784	986521	91A467	187	481
21	97248A	53417	5642	36812	3276	35784	986521	9A1467	1A87	891
22	97248	5A3417	5642A	36812	3A276	35784	986521	91467	187	532
23	982467	534187	56A42	3A612	3276	4A3571	916528	9721	817	643
24	857246	41753A	9A2564	93612A	863271	81435	215	651	34A	3942
25	857246	941753	9256A4	93A612	863271	814A35	215	651	342	643
26	24965A	75341A	2564	691236	7A1632	843519	52A	946	8614	5721
27	865724	753941	925A64	936812	716A32	843A51	521	614	342	563
28	824657	875341	9A4256	96123A	71632	93514	8152	721	64A3	943
29	824657	875341	94256A	96123	71632	9A3514	8152	721	643A	693
30	935862	91653A	4A2519	9A3	781326	75218	856	7615	4312A	3492

TRI-LINEAR POLYHEDRA

OF

11 FACES

WITH

MEC ≤ 6

1	98A4	7534A8	5642	91A236	3276	357894	5286	AB9672	81468	18824	98A1
2	98A4	753BA8	564B2	91AB36	3276	357894	5286	A19672	1468	18284	34A2
3	98A4	75BA8	564B	91AB36	3B276	357894	5286	A19672	1468	18284	534A2
4	A49882	753A18	A2564	91A36	7632	578943	5286	96721B	8B146	3412	981
5	A4B982	753A18	A2564	981A36	7632	578943	5286	96721	81846	3412	491
6	AB982	753A18	A2564	9BA36	7632	578943	5286	96721	81B46	34812	A491
7	A4982	75BA18	AB564	91A36	763R2	578943	5286	96721	8146	34128	53A2
8	A4982	7B3A18	A2B564	91A36	763B	578943	5B286	96721	8146	3412	7532
9	A498B2	753A18	A2564	91A36	7632	578943	52886	967B1	8146	3412	1872
10	A4982	7BA18	AB564	91A36	763B	578943	5B286	96721	8146	3412B	753A2
11	9B824	1875A4	A564	912A36	3A276	357894	5286	1B9672	B1468	3425	981
12	9824	18B5A4	A564	912A36	3A2876	357894	5886	1967B2	1468	3425	8752
13	98824	187A34	A5642	91236	A763	943578	5A286	1B9672	81468	5327	981
14	9824	187B4	A564B	912B36	A763	943578	5AB286	19672	1468	53B7	7A342
15	98AB4	753A8	564A2	91BA36	7632	578943	5286	19672A	1468	818234	A41
16	98A4B	753A8	564A2	9B1A36	7632	578943	5286	19672A	1B468	18234	491
17	98A4	753BA8	564AB2	91A36	7632	578943	5286	19672A	1468	182B34	3A2
18	982AB4	75A18	4A56	91BA36	3A276	357894	5286	72196	8146	34B125	A41
19	982BA4	75AB18	4A56	91A36	3A276	357894	5286	72196	8146	341B25	2A1
20	9882A4	75A18	4A56	91A36	3A276	357894	5286	721896	88146	34125	981
21	894AB6	34975	5A42	3A192	3276A	813A57	86529	1679	87241	356B14	A61
22	8894A6	34975	5A42	3A192	3276A	81A57	86529	81679	87241B	35614	891
23	A824B9	753418	5642	369B12	3276	357894	5286	A96721	A18468	198	491
24	A8249B	753418	5642	36912	3276	357894	5286	A96721	AB1468	1898	9A1
25	A4689	5B3497	56428	A92361	3B276	357814	52986	1679	A13724	194	532
26	A4689	53497B	5642	A92361	32B76	357814	5B2986	1679	A13724	194	752
27	A9468B	53497	5642	36192	3276	357814	52986	AB1679	A87241	1B89	8A1
28	A9468	5B3497	5642B	36192	3B276	357814	52986	A1679	A87241	189	532
29	A29487	A75391	564B92	9B3681	6327	84357	A18652	4671	3B412	721	493
30	A29487	A75391	56B492	93B681	6327	84B357	A18652	4671	3412	721	643
31	A72948	53B917	9B2564	93681	6327	57843	A86521	A1467	2B341	871	392
32	A72948	53917	925B64	93681	6B327	57843B	A86521	A1467	2341	871	563
33	A72948	53917	92564	936B81	6327	578B43	A86521	A14B67	2341	871	684
34	AB7294	53B917	9B2564	A19368	3276	57843	52186	A4671	2B341	814	392
35	A87294	5B3917	92B564	A19368	3B276	57843	52186	A4671	2341	814	532
36	A87294	53917	92564	A19368	3276	57B843	521B86	A46B71	2341	814	786
37	982465	875341	AB4256	A6123B	791632	A3514	8952	9721	7815	64B3	A43
38	982465	875341	A4256	A6123	791632	A3514	88952	98721	78815	643	897
39	948A72	917534	5B642	923681	B3276	385784	A86521	A1467	124	871	563
40	94872	917534	A6425B	923681	AB3276	A57843	86521	7146	124	3856	5A3
41	A89724	5B3417	5642B	A12368	3B276	35784	986521	91A467	187	481	532
42	A97248	5B3417	5642B	36812	3B276	35784	521986	A14679	A871	918	532
43	982467	534187	AB4256	A6123B	3276	A35714	916528	9721	817	4B36	A43
44	862935	A91653	A2519B	AB9	781326	75218	856	7615	4B312A	4923B	94A3

TRI-LINEAR POLYHEDRA

OF

12 FACES

WITH

MEC ≤ 6

1	BCA49	7534A8	5642	1A2369	3276	357894	5286	B9672A	B1468	1C8824	C198A	BA1
2	BAC9	7534A8	5642	CA2369	3276	357894	5286	B9672A	B1C468	C18824	198A	A491
3	BA49	753CA8	564C2	1AC369	3276	357894	5286	B9672A	B1468	1B82C4	198A	34A2
4	BA49	7C34A8	5642C	1A2369	3C76	357894	5C286	B9672A	B1468	1B824	198A	7532
5	BA49	75CA8	564C	1AC369	3C276	357894	5286	B9672A	B1468	1B82C4	198A	534A2
6	BAC49	753CA8	564C2	1C369	3276	357894	5286	B9672A	B1468	1B82C	198A	1A234
7	98A4	753CA8	BC2564	91AB36	7632	578943	5286	19672A	1468	B4182C	34AC	38A2
8	98A4	75CBA8	BC564	91AB36	763C2	578943	5286	19672A	1468	B4182	34A2C	53B2
9	98A4	753BAC	B2564	91AB36	7632	578943	52C86	1967CA	1468	B418C2	34A2	A872
10	98A4	75CA8	BC564	91AB36	763C2	578943	5286	19672A	1468	B4182C	34AC	53BA2
11	98A4	753BA8	B2564	91AB36	7632	57C943	528C6	19C72A	146C8	B4182	34A2	7896
12	98A4	753BA8	B2564	91AB36	7C632	5C943	528C	19C72A	146C8	B4182	34A2	57896
13	98A4	75BCA8	B564	91AB36	3B276	357894	5286	19672A	1468	182C84	34AC25	BA2
14	98A4	75CBA8	B564	91AB36	3BC276	357894	5286	19672A	1468	18284	34A2C5	5B2
15	98A4	7C5BA8	B564	91AB36	3B2C76	357894	5C286	19672A	1468	18284	34A25	752
16	98AC4	75BA8	B564	91CB36	3B276	357894	5286	19672A	1468	1828C	34CA25	1AB4
17	98AC4	75BA8	B564C	91C36	3B276	357894	5286	19672A	1468	1828C	3CA25	1AB34
18	98AC	75BA8	B564	9CB36	3B276	357894	5286	19672A	1C468	1828C	34CA25	91AB4
19	98A4	75BA8	B564	91AB36	3B27C6	35C94	528C	19C72A	146C8	182B4	34A25	57896
20	B9C82A	753A18	564A2	BA369	7632	578943	5286	721C96	B468C1	B1234	A491	981
21	BC982A	753A18	564A2	BA369	7632	578943	5286	72196	B4681C	B1234	A49C1	891
22	B982AC	753A18	564A2	BA369	7632	578943	5286	72196	B4681	BC1234	A491C	AB1
23	982AC	753A18	564A2	BA369	7632	578943	5286	72196	B4681C	BC1234	A49C	AB91
24	B982A	7C3A18	564A2C	BA369	763C	578943	5C286	72196	B4681	B1234	A491	7532
25	B982CA	75C18	564AC	BA369	763C2	578943	5286	72196	B4681	B1C34	A491	53A12
26	982AC4	75BA18	B564A	91CA36	B2763	789435	5286	96721	8146	B34C12	53A2	A41
27	9C82A4	75BA18	B564A	91A36	B2763	789435	5286	96721C	8C146	B3412	53A2	981
28	982A4C	75BA18	B564A	9C1A36	B2763	789435	5286	96721	81C46	B3412	53A2	491
29	A49C82	A187B3	B564A2	91A36	B763	578943	5B286	96721C	8C146	4123	5327	981
30	A4C982	A187B3	B564A2	9C1A36	B763	578943	5B286	96721	81C46	4123	5327	491
31	AC4982	A187B3	B564A2	91CA36	B763	578943	5B286	96721	8146	4C123	5327	A41
32	A4982	A18CB3	B564A2	91A36	B763	578943	5BC86	967C21	8146	4123	532C7	8782
33	A4982	A187B3	B564A2	91A36	BC763	578943	5CB286	96721	8146	4123	C5327	B75
34	A4982	A187B3	B564A2	91A36	B7C63	5C8943	5B28C	96C721	8146	4123	5327	5786
35	A49882	B753A1	A2564C	AC3691	7632	578943	B8652	B1967	8146	3C412	8721	4A3
36	982AC4	7BA18	564AB	91CA36	3B76	578943	5B286	96721	8146	34C12B	53A27	A41
37	982CA4	7BAC18	564AB	91A36	3B76	578943	5B286	96721	8146	341C2B	53A27	2A1
38	9C82A4	7BA18	564AB	91A36	3B76	578943	5B286	96721C	8C146	3412B	53A27	981
39	982A4	7BA18C	564AB	91A36	3B76	578943	5B2C86	967C21	8146	3412B	53A27	872
40	982A4	7BA18	564AB	91A36	3B7C6	5C943	5B28C	9C721	8146C	3412B	53A27	57896

41	98C24	1C87B4	A564B	912B36	A763	943578	5AB286	C19672	1468	53B7	A3427	821
42	9C824	187B4	A564B	912B36	A763	943578	5AB286	1C9672	C1468	53B7	A3427	981
43	9C24	1C87B4	A564B	912B36	A763	943578	5AB286	C9672	C1468	53B7	A3427	9821
44	B82A49	753A18	A2564C	AC3691	7632	578943	5286	B96721	B1468	3C412	981	4A3
45	B8249C	75A418	A564	A36912	3A276	357894	5286	B96721	BC1468	3425	1C98	9B1
46	B8249	75A418	AC564	A36912	3CA276	357894	5286	B96721	B1468	C3425	198	A53
47	B824C9	A34187	A5642	9C1236	A763	578943	5A286	B96721	B1C468	5327	198	491
48	B8249C	A34187	A5642	91236	A763	578943	5A286	B96721	BC1468	5327	1C98	9B1
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50	B8249	A34187	A5642	91236	AC763	578943	5CA286	B96721	B1468	C5327	198	A75
51	B498A	75C3A8	564A2C	BA3691	763C2	578943	5286	72A196	1468	B18234	1A4	532
52	B498A	7C53A8	564A2	BA3691	7632C	578943	5C286	72A196	1468	B18234	1A4	752
53	BC98A4	753A8	564A2	B1A369	7632	578943	5286	72A196	B4681C	23418	9C14	B91
54	B98A4	753CA8	564AC2	B1A369	7632	578943	5286	72A196	B4681	2C3418	914	3A2
55	B98A4	7C53A8	564A2	B1A369	7632C	578943	5C286	72A196	B4681	23418	914	752
56	B4982A	7C5A18	564A	BA3691	763A2C	357894	5C286	72196	B146	B12534	A41	752
57	B82A49	7C5A18	4A56	3691A	3A2C76	357894	5C286	B96721	B1468	34125	981	752
58	B82A49	75A18	4AC56	3691A	3CA276	357894	5286	B96721	B1468	C34125	981	A53
59	B6894A	3497C5	425A	3A192	32C76A	BA5781	865C29	7916	87241	B14356	A61	752
60	B6894A	349C75	425A	3A192	3276A	BA5781	8652C9	7916	87C241	B14356	A61	972
61	B6894A	3C4975	4C25A	3A192C	3276A	BA5781	86529	7916	87241	B14356	A61	342
62	B6894A	34975	425A	3A192	3276A	BA5781	86529C	7C916	8C7241	B14356	A61	987
63	B94A68	3C4975	5A4C2	3A192C	3276A	A5781	86529	B1679	B87241	35614	891	342
64	B94A68	34975C	5A42C	3A192	3C276A	A5781	86529	B1679	B87241	35614	891	532
65	B94A68	34975	5A42	3A192	3276A	A57C81	8C6529	B16C79	B87241	35614	891	786
66	A4689	34975C	B5642C	A92361	BC2763	814357	86529	1679	A18724	194	53C	5B32
67	BA9468	5C3497	5642C	36192	3C276	357814	52986	B1679A	A87241	B891	A18	532
68	A72948	B91753	B25649	6C8193	6327	578C43	A86521	A14C67	B3412	871	923	684
69	A87294	B91753	B25649	A19368	7C632	5C7843	C52186	A4671	B3412	814	923	765
70	A87294	B91753	B25649	A19368	7632	57C843	5218C6	A46C71	B3412	814	923	786
71	982465	875341	B4256C	BA6123	791632	AC3514	8952	9721	7815	BC64	A43C	6AB3
72	982465	875341	B4256A	BA6123	791632	A3514	8C952	9C721	7C815	B364	A43	897
73	948A72	917534	B6425C	923681	BC3276	B57843	A86521	A1467	124	871	3C56	5B3
74	A89724	34175C	B5642C	A12368	BC2763	35784	986521	91A467	187	481	53C	5B32
75	A89724	B34175	B5C642	A12368	B276C3	3C5784	986521	91A467	187	481	532	563
76	A97248	34175C	B5642C	36812	BC2763	43578	986521	A14679	A871	918	53C	5B32
77	862935	A91653	BA2519	B9AC	781326	75218	856	7615	4B312A	C4923B	4CA39	AB4

TRI-LINEAR POLYHEDRA

OF

13 FACES

WITH

MEC $\leq$ 6

1	BDC9	7534A8	5642	CA2369	3276	357894	5286	B9672A	B1C468	CDB824	D198A	1DA49	BAC1
2	BAC9	753DA8	564D2	CD369	3276	357894	5286	B9672A	B1C468	C1B82D	198A	1AD49	CA234
3	BA49D	753CA8	C2564	C3691A	7632	578943	5286	B9672A	BD1468	1B82C4	1D98A	34A2	9B1
4	BA49	75DCA8	CD564	C3691A	763D2	578943	5286	B9672A	B1468	1B82C4	198A	34A2D	53C2
5	BA49	7D3CA8	C2D564	C3691A	763D	578943	5D286	B9672A	B1468	1B82C4	198A	34A2	7532
6	BA49	7DCA8	CD564	C3691A	763D	578943	5D286	B9672A	B1468	1B82C4	198A	34A2D	753C2
7	BA49	753CA8	C256D4	C3D91A	7632	5789D3	5286	B9672A	B14D68	1B82C4	198A	34A2	3694
8	BAD49	753CA8	C2564	C3691D	7632	578943	5286	B9672A	B1468	1B82CD	198A	34DA2	1AC4
9	BA4D9	753CA8	C256D4	C3D1A	7632	5789D3	5286	B9672A	B1D68	1B82C4	198A	34A2	36914
10	BA49	753CA8	C2564	C3691A	7632	57D943	528D6	B9D72A	B146D8	1B82C4	198A	34A2	7896
11	BA49	753CA8	C2564	C3691A	7632	57D943	528D6	BD72A	B146D	1B82C4	19D8A	34A2	B9678
12	BA49	753CD8	C2564	C3691A	7632	578943	5286	B9672D	B1468	1BDC4	198DA	34AD2	B82CA
13	BDA49	C34A87	C5642	1A2369	C763	578943	5C286	B9672A	B1468	1D8824	D198A	5327	BA1
14	BA49D	75CA8	C564	1AC369	3C276	357894	5286	B9672A	BD1468	1B82C4	1D98A	34A25	9B1
15	BA49	75DCA8	C564	1AC369	3CD276	357894	5286	B9672A	B1468	1B82C4	198A	34A2D5	5C2
16	BA49	7D5CA8	C564	1AC369	3C2D76	357894	5D286	B9672A	B1468	1B82C4	198A	34A25	752
17	BAD49	75CA8	C564	1DC369	3C276	357894	5286	B9672A	B1468	1B82CD	198A	34DA25	1AC4
18	BAD49	75CA8	C564D	1D369	3C276	357894	5286	B9672A	B1468	1B82CD	198A	3DA25	1AC34
19	BA49	75CA8	C564	1AC369	3C27D6	35D94	528D	B9D72A	B146D8	1B82C4	198A	34A25	57896
20	BA49	75CD8	C564	1AC369	3C276	357894	5286	B9672D	B1468	1BDC4	198DA	34AD25	B82CA
21	BAC4D9	753CA8	564C2	9D1C36	7632	578943	5286	B9672A	B1D468	B82C1	A198	341A2	491
22	BACD49	753CA8	564C2	91DC36	7632	578943	5286	B9672A	B1468	B82C1	A198	34D1A2	C41
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24	BAC49	7DCA8	564CD	91C36	763D	578943	5D286	B9672A	B1468	B82C1	A198	341A2D	753C2
25	BAC49	753CA8	564DC2	91CD36	7632	578943	5286	B9672A	B1468	B82C1	A198	3D41A2	4C3
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27	98A4	75DBA8	C564B	91AB36	CD2763	789435	5286	19672A	1468	182B4	C34A2D	53BD	5CB2
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36	98AD4	C753BA	B2564D	91D36	7632	578943	52C86	1967CA	1468	BD18C2	3DA2	72A8	1AB34
37	98A4	C753BA	B2564	91AB36	7D632	5D943	52C8D	19D7CA	146D8	B418C2	34A2	72A8	57896
38	98A4	75DCA8	BC564	91AB36	763CD2	789435	5286	19672A	1468	B4182C	C34A	BA2D53	5C2
39	98A4	7D5CA8	BC564	91AB36	763C2D	789435	5D286	19672A	1468	B4182C	C34A	BA253	752
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46 C498AD 75BA8 564B 91CB36 763B2 357894 5286 72A196 1468 CD182B CA2534 1DAB4 AC1
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TRI-LINEAR POLYHEDRA

OF

14 FACES

WITH

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153	B982CA	D5C187	4AC56	BEA369	D763C2	789435	D2865	96721	B4681	B1C34E	AE491	3A125	752	BA4
154	B982CA	D5C187	4AC56	BA369E	D763C2	789435	D2865	96721	BE4681	B1C34	A4E91	3A125	752	9B4
155	B982CA	D75C18	4ACE56	BA369	3EC276	943578	D8652	D21967	B4681	B1C34	A491	5E3A12	728	C53
156	B982CA	D75C18	4AEC56	BA369	3C276	943578	D8652	D21967	B4681	B1CE34	A491	53EA12	728	AC3
157	B982CA	D75C18	4AC56	BA369E	3C276	943578	D8652	D21967	BE4681	B1C34	A4E91	53A12	728	9B4
158	D982A4	CB3A18	A2B564	D1A369	BE763	578943	5EBC86	C21967	D4681	4123	C7E532	7B28	914	B75
159	D982A4	B3A187	B564A2	D1A369	B7EC63	C89435	CE5B28	C72196	D4681	4123	7532	5E786	914	7C5
160	D982A4	B3A187	B564A2	D1A369	BE7C63	C89435	C5EB28	C72196	D4681	4123	7E532	5786	914	B75

161	D4982A	87EBA1	B564A	DA3691	3B7C6	35C94	5BE28C	9C721	6C814	D12B34	2E753A	57896	A41	7B2
162	D4982A	87BA1	B564A	DA3691	3B7CE6	35EC94	5B28C	9C721	6C814	D12B34	2753A	E57896	A41	C65
163	D4982A	87BA1	B564A	DA3691	3B7EC6	35C94	E5B28C	9C721	6C814	D12B34	2753A	5E7896	A41	7C5
164	DEC249	1C87B4	A564B	B36912	A763	578943	5AB286	C9672	D1468C	53B7	A3427	D9821E	CE19	DC1
165	DC249	1C87B4	AE564B	B36912	A763E	578943	5AB286	C9672	D1468C	5E3B7	A3427	D9821	C19	A53
166	DC249	1C87B4	A564BE	B36912	A763	578943	5AB286	C9672	D1468C	53EB7	AE3427	D9821	C19	BA3
167	C249	1C87B4	DA564B	12B369	A763	578943	5AB286	CE9672	C1468E	DB753	D3427A	19E82	A3B	C98
168	982465	875341	CB4256	BA6123	791632	AC3514	DE9528	D7219	D8157E	BC64	CA43	AB36	89E7	D97
169	982465	875341	CB4256	BA6123	791632	AC3514	D9528	D7219	D8157	BEC64	CEA43	AEB36	897	BCA
170	C82A49	A187B3	A2B564	A3691	D763BE	943578	DB2865	C96721	C1468	4123	DE5327	981	5EB7	BD5
171	C982A4	A187B3	A2B564	C1A369	D763BE	894357	DB2865	96721	C4681	4123	DE5327	914	5EB7	BD5
172	C4982A	B3A187	B564A2	CA3691	D763BE	943578	DB2865	96721	8146	C1234	DE5327	A41	5EB7	BD5
173	C4982A	D7BA18	564ABE	CA3691	3EB76	943578	D865B2	D21967	8146	C12834	5E3A27	A41	872	B53
174	C82A49	78A18	DAB564	D3691A	BE763	578943	5EB286	C96721	C1468	D412B3	E53A27	981	4A3	B75
175	C2498	C87B41	564BAE	912B36	DA763E	943578	5AB286	C19672	1468	DE3B75	A3427	182	A5E	AD53
176	DC8249	B4187	AE564B	2B3691	A763E	578943	5AB286	C96721	D1468C	5E3B7	A3427	D981	C19	A53
177	CB8249	75A418	D564AE	A36912	DA2763	789435	5286	B96721	C1468B	DE3425	C981	B19	3EA5	AD3
178	C9B824	7A3418	5642AE	C12369	DA763E	578943	5A286	B96721	B1C468	DE3275	198	491	A5E	AD53
179	C9B824	7A3418	D5642A	C12369	DAE763	578943	5EA286	B96721	B1C468	D327E5	198	491	A53	A75
180	CB8249	7A3418	5642AE	36912	DA763E	578943	5A286	B96721	C1468B	DE3275	C981	B19	A5E	AD53
181	CB8249	A34187	A5642	36912	D763AE	435789	DA2865	B96721	C1468B	DE5327	C981	B19	5EA7	AD5
182	C98A4B	53A87E	A2564	B1A369	D7632E	357894	DE2865	72A196	CB4681	34182	C149	B91	75E	7D52
183	B94A68	C49753	C25DA4	C3A192	D3276A	7E81A5	8E6529	B16E79	B87241	D56143	891	342	5A3	786
184	862935	653A91	BA2519	DB9ACE	781326	75218	856	7615	4B312A	C4923B	DCA394	DE4AB	CB4E	CD4

TRI-LINEAR POLYHEDRA

OF

15 FACES

WITH

MEC $\leq$ 6

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1 DFEB 7534A8 5642 369CA2 3276 357894 5286 72AB96 EC468B DB824C D1E98A EFDA49 F1BAC 1FC98 DCE1
2 DFC9B E34A87 E5642 369CA2 E763 578943 5E286 72AB96 1C468B DB824C D198A 1FDA49 F1BAC 5327 DC1
3 DC9B E34A87 E56F42 3FCA2 E763 5789F3 5E286 72AB96 1CF68B DB824C D198A 1DA4F9 1BAC 5327 369C4
4 DC9BF 7534A8 56E42 3ECA2 7632 5789E3 5286 72AB96 1CE68B DB824C DF198A 1DA4E9 1FBAC 4369C BD1
5 DC9B 75F4A8 56E4F 3ECA2F 763F2 5789E3 5286 72AB96 1CE68B DB824C D198A 1DA4E9 1BAC 4369C 5342
6 DC9B 7F4A8 56E4F 3ECA2F 763F 5789E3 5F286 72AB96 1CE688 DB824C D198A 1DA4E9 1BAC 4369C 75342
7 DC9B 7534A8 56EF42 3FECA2 7632 5789E3 5286 72AB96 1CE68B DB824C D198A 1DA4E9 1BAC 4F369C E43
8 DC9B 7534AF 56E42 3ECA2 7632 5789E3 52F86 7FB96 1CE68B DBF24C D198FA 1DA4E9 1BAC 4369C 72AB8
9 DCF9B 7534A8 56E42 3ECA2 7632 5789E3 5286 72AB96 1FE68B DB824C D198A 1DA4EF 1BAC 4369FC 1CE9
10 DC9B 7534A8 56E42 3ECA2 7632 578FE3 5286 72ABF6 1CEFB DB824C D19F8A 1DA4E9 1BAC 436F9C E6889
11 DC9B 7534A8 56E42 3EFA2 7632 5789E3 5286 72AB96 1CE68B DB824F D198A 1DFE9 1BAFC 4369CF DA4EC
12 BAC9 75EDA8 EF564D CD369 E2763F 789435 5286 B9672A B1C468 1B82DC 198A 1AD49 E34CA2 5F3D2 E53
13 BAC9 75EDA8 E5F4D CD3F69 E276F3 7894F5 5286 B9672A B1C468 1B82DC 198A 1AD49 E34CA2 53D2 5643
14 BAC9 75EDA8 E564F CDF369 E2763 789435 5286 B9672A B1C468 1B82DC 198A 1AD49 EF4CA2 53FD2 4DE3
15 BAC9 75EDA8 E564FD CF369 E2763 789435 5286 B9672A B1C468 1B82DC 198A 1ADF49 E3FCA2 53D2 CD34
16 BAC9 75EDA8 E564D CD36F9 E2763 7F435 528F6 B9F72A B1C4F8 1B82DC 198A 1AD49 E34CA2 53D2 78946
17 BAC9 75EDA8 E564D CD369 E2763 7F9435 528F6 BF72A B1C46F 1B82DC 19F8A 1AD49 E34CA2 53D2 B9678
18 BACF9 75EDA8 E564D CD369F E2763 789435 5286 B9672A B1F468 1B82DC 198A 1AD4F E34CA2 53D2 1C49
19 BACF 75EDA8 E564D CD369F E2763 789435 5286 B9672A BF468 1B82DC 1F98A 1AD4F E34CA2 53D2 B1C49
20 BAC9 75EDA8 E564F CF369 E2763 789435 5286 B9672A B1C468 1B82DC 198A 1ADF49 EFCA2 53FD2 E34CD
21 BAC9 7FEDA8 564DE CD369 3E76 578943 5EF286 B9672A B1C468 1B82DC 198A 1AD49 2E34CA 53D2F7 7E2
22 BAC9 7EDA8 564DEF CD369 3FE76 578943 5E286 B9672A B1C468 1B82DC 198A 1AD49 2E34CA 5F3D27 E53
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25 BAC9 7EDA8 564DE CD369 3EF76 578943 5FE286 B9672A B1C468 1B82DC 198A 1AD49 2E34CA F53D27 E75
26 BAC9 7EDA8 564DE CD36F9 3E76 57F43 5E28F6 B9F72A B1C4F8 1B82DC 198A 1AD49 2E34CA 53D27 78946
27 BAC9 7EDAF8 564DE CD369 3E76 578943 5E286 B9672F B1C468 1BF2DC 198FA 1AD49 2E34CA 53D27 2AB8
28 BAC9 7EDA8 564DE CD369 3E76 57F943 5E28F6 BF72A B1C46F 1B82DC 19F8A 1AD49 2E34CA 53D27 B9678
29 BACF 7EDA8 564DE CD369F 3E76 578943 5E286 B9672A BF468 1B82DC 1F98A 1AD4F 2E34CA 53D27 B1C49
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33 BAC9 753DA8 D2564F EF369C 7632 578943 5286 B9672A B1C468 1B82DC 198A E491AD ECA23F 4CDF 4ED3
34 BAC9 753DA8 ED2564 E369C 7632 57F943 528F6 BF72A B1C46F 1B82DC 19F8A E491AD ECA23 4CD3 B9678
35 BAC9 53DF87 564D2 CD369 7632 57E943 528E6 BE72FA 1C46EB 1B8FDC 19E8A 1AD49 34CAF2 78B96 DA82
36 BAC9 53DA87 564FD2 CDF369 7632 57E943 528E6 BE72A 1C46EB 1B82DC 19E8A 1AD49 3F4CA2 78B96 4D3
37 BA49F 75ECA8 D564C 1AC369 DE2763 789435 5286 B9672A BF1468 1B82C4 1F98A ED34A2 E53C DC25 981
38 BA49 7FECA8 D564C 1AC369 DEF763 789435 5F286 B9672A B1468 1B82C4 198A ED34A2 E53C DC2F5 75E2
39 BA49 75ECA8 D56F4C 1AC3F9 DE2763 789F35 5286 B9672A B14F68 1B82C4 198A ED34A2 E53C DC25 3694
40 BAF49 75ECA8 D564FC 1F369 DE2763 789435 5286 B9672A B1468 1B82CF 198A ED3FA2 E53C DC25 1AC34
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41	BA49	75ECA8	D5F64C	1AC369	DE27F3	78943F	F5286	B9672A	B1468	1B82C4	198A	ED34A2	E53C	DC25	7635
42	BA49	75ECA8	DF564C	1AC369	E2763F	789435	5286	B9672A	B1468	1B82C4	198A	ED34A2	EF3C	DC25F	3DE5
43	BA49	7FECA8	D564C	1AC369	DF763	789435	5F286	B9672A	B1468	1B82C4	198A	ED34A2	EF53C	DC2F	DE275
44	BA49	75ECA8	D564C	1AC369	DE2763	7F9435	528F6	B9F72A	B146F8	1B82C4	198A	ED34A2	E53C	DC25	7896
45	BA49F	EDCA87	CD564	1AC369	E763D	357894	E2865	B9672A	BF1468	1B82C4	1F98A	D34A2	E53C2	75D2	981
46	BA49	DCA87F	CD564	1AC369	E763D	357894	EF2865	B9672A	B1468	1B82C4	198A	D34A2	E53C2F	75DF	7ED2
47	BA49	EDCA87	CDF564	1AC369	E763FD	357894	E2865	B9672A	B1468	1B82C4	198A	D34A2	E5F3C2	75D2	D53
48	BA49	EDCA87	CFD564	1AC369	E763D	357894	E2865	B9672A	B1468	1B82C4	198A	DF34A2	E53FC2	75D2	CD3
49	BA49	EDCA87	CD564	1AC369	EF763D	357894	E2865F	B9672A	B1468	1B82C4	198A	D34A2	E53C2	7F5D2	E75
50	BA49	EDCA87	CD564	1AC369	E763DF	357894	E2865	B9672A	B1468	1B82C4	198A	D34A2	EF53C2	75FD2	DE5
51	BA49	EDCA87	CD564	1AC369	E763D	357F94	E28F65	BF72A	B146F	1B82C4	19F8A	D34A2	E53C2	75D2	B9678
52	BA49	75DCA8	D5FE4C	E91AC3	D276F3	EF5789	5286	B9672A	B14E68	1B82C4	198A	D34A2	53C2	3F694	56E3
53	BAF49	75DCA8	D56E4C	E91FC3	D2763	E35789	5286	B9672A	B14E68	1B82CF	198A	D34FA2	53C2	3694	1AC4
54	BA4F9	75DCA8	D56E4C	EF1AC3	D2763	E35789	5286	B9672A	B1FE68	1B82C4	198A	D34A2	53C2	369F4	E914
55	BA49	75DCA8	D5FE4C	E91AC3	D27F3	EF789	5286F	B9672A	B14E68	1B82C4	198A	D34A2	53C2	3F694	E3576
56	BA49	75DCA8	D56E4C	E91AC3	D2763	E357F9	528F6	BF72A	B14E6F	1B82C4	19F8A	D34A2	53C2	3694	B9678
57	BA4F	75DCA8	D56E4C	EF1AC3	D2763	E35789	5286	B9672A	BFE68	1B82C4	1F98A	D34A2	53C2	369F4	B14E9
58	BA49	75DCF8	D56E4C	E91AC3	D2763	E35789	5286	B9672F	B14E68	1BFC4	198FA	D34AF2	53C2	3694	B82CA
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60	BAE49	75DCA8	D564FC	EF3691	D2763	789435	5286	B9672A	B1468	E1B82C	198A	D3FEA2	53C2	1ACF4	EC34
61	BAE4F9	75DCA8	D56F4C	EC3F1	D2763	789F35	5286	B9672A	B1F68	E1B82C	198A	D34EA2	53C2	1AC4	36914
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63	BAE4F9	75DCA8	D564EC	9F1E36	D2763	789435	5286	B9672A	B1F468	B82CE1	198A	D3EA2	53C2	41AC3	491
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65	BAE49F	75DCA8	D564EC	91E36	D2763	789435	5286	B9672A	BF1468	B82CE1	1F98A	D3EA2	53C2	41AC3	981
66	BAE49	75DCA8	D5F4EC	91E3F6	D276F3	7894F5	5286	B9672A	B1468	B82CE1	198A	D3EA2	53C2	41AC3	5643
67	BAE49	75DCA8	D564EF	91E36	D2763	789435	5286	B9672A	B1468	B82CE1	198A	DFEA2	53FC2	41ACF3	ECD3
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72	BAE49	75DCF8	D564EC	91E36	D2763	789435	5286	B9672F	B1468	BFCE1	198FA	D3EAF2	53C2	41AC3	B82CA
73	BA49F	DCA875	D5E64C	1AC369	E3D27	E78943	E5286	B9672A	BF1468	1B82C4	1F98A	D34A2	53C2	5763	981
74	BA49	DCA875	D5E64C	1AC369	E3D27F	E78943	EF5286	B9672A	B1468	1B82C4	198A	D34A2	53C2	5F763	7E5
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77	BA49	DCA875	D564CF	1AC369	D2763	E94357	E6528	E72AB9	B146E8	1B82C4	198A	DF34A2	53FC2	7896	CD3
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79	BA49	DCAF75	D564C	1AC369	D2763	E94357	E652F8	E7FB9	B146E8	1BF2C4	198FA	D34A2	53C2	7896	72AB8
80	BA49	DCA875	D5E4CF	1AC3E9	76E3D2	789E5	6528	B9672A	B14E68	1B82C4	198A	DF34A2	3FC25	35694	CD3

81	BA4F9	DCA875	D5E4C	1AC3EF	76E3D2	789E5	6528	B9672A	B1FE68	1B82C4	198A	D34A2	3C25	3569F4 E914
82	BA49	DCA875	D5E4C	1AC3E9	76E3D2	78F9E5	6528	BF672A	B14E6F	1B82C4	19F8A	D34A2	3C25	35694 B968
83	BA49	DCA875	D5E4C	1AC3E9	76E3D2	7F9E5	6528F	BF72A	B14E6F	1B82C4	19F8A	D34A2	3C25	35694 B9678
84	BA4F	DCA875	D5E4C	1AC3EF	76E3D2	789E5	6528	B9672A	BFE68	1B82C4	1F98A	D34A2	3C25	3569F4 B14E9
85	BA49	DCF875	D5E4C	1AC3E9	76E3D2	789E5	6528	B9672F	B14E68	1BFC4	198FA	D34AF2	3C25	35694 B82CA
86	9FBA4	DCA875	D564C	1AC369	D2763	357E94	8E652	BE72A	F146EB	1B82C4	1F9E8A	D34A2	53C2	78B96 9B1
87	9BA4	DF875	D564C	1AC369	D2763	357E94	8E652	BE72FA	146EB	1B8FC4	19E8A	D34AF	53CF2	78B96 DCA82
88	9BA4	DCA875	DF564C	1AC369	D2763F	357E94	8E652	BE72A	146EB	1B82C4	19E8A	D34A2	5F3C2	78B96 D53
89	9BA4	DCA875	D564CF	1AC369	D2763	357E94	8E652	BE72A	146EB	1B82C4	19E8A	DF34A2	53FC2	78B96 CD3
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91	9BA4	DCA875	D5F64C	1AC369	D27F3	3FE94	8EF52	BE72A	146EB	1B82C4	19E8A	D34A2	53C2	78B96F 357E6
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97	9BA4	DCF875	D564C	1AC369	D2763	357E94	8E652	BE72F	146EB	1BFC4	19E8FA	D34AF2	53C2	78B96 B82CA
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235	E98AD4	7F5CA8	BC564D	E1D369	763C2F	789435	5F286	72A196	E4681	BD182C	C3DA	BA253	B341A	914	752
236	98A4	753BA8	EB256D	1ABD69	7FC632	5C94D3	CF528	19C72A	146C8	182B4	ED4A23	78965F	E364B	DB3	7C5
237	E98A4	753BA8	B256DF	E1AD69	7C632	D35C94	C528	72A19C	E46C81	BD4182	3FDA2	78965	BF364A	149	DB3
238	C982A	187D3A	D564A2	BA369	E763CF	578943	ED2865	19672	CB4681	BC1234	CA49	B91A	EF5327	5FD7	DE5
239	E982AB	DC3A18	564A2C	BFA369	C763	578943	5CD86	D21967	EB4681	4FB123	E1AF49	D7532	7C28	B91	BA4
240	E982AB	DC3A18	564A2C	BA369	CF763	578943	5FCD86	D21967	EB4681	4B123	E1A49	D7F532	7C28	B91	C75

241	E982AB	DC3A18	564A2C	BA369	C763	578943	5CFD86	D21967	EB4681	4B123	E1A49	DF7532	7FC28	B91	CD7
242	D249CF	D87B41	A564B	B36912	A763	578943	5AB286	DC9672	C1468	53B7	A3427	EF198D	EC821F	CDF	CED1
243	ED249C	D87B41	AF564B	B36912	A763F	578943	5AB286	DC9672	C1468	5F3B7	A3427	E198D	EC821	CD1	A53
244	ED249C	D87B41	A564BF	B36912	A763	578943	5AB286	DC9672	C1468	53FB7	AF3427	E198D	EC821	CD1	BA3
245	ECD249	D87B41	A564BF	B36912	A763	578943	5AB286	DC9672	E1468C	53FB7	AF3427	E98D1	C821	C19	BA3
246	EBDA49	C34A87	CF5642	3691A2	C763F	578943	5C286	72AB96	E1468B	DB8241	D1E98A	5F327	1BA	981	C53
247	EDA49B	C34A87	CF5642	3691A2	C763F	578943	5C286	9672A8	B1468	DB8241	E198AD	5F327	EBA1	D1B	C53
248	EBA49D	75FCA8	C564	3691AC	3CF276	357894	5286	72AB96	D1468B	2C41B8	ED98A1	34A2F5	E198	DB1	5C2
249	EBA49D	7F5CA8	C564	3691AC	3C2F76	357894	5F286	72AB96	D14688	2C4188	ED98A1	34A25	E19B	DB1	752
250	D98AC4	E58A87	CFB564	D1C369	E763B2	789435	E2865	72A196	D4681	8C182	3FCA25	ABF341	914	752	CB3
251	D82AB9	C3A187	C564A2	EA369B	CF763	578943	5FC286	D96721	D1B468	EB1234	E491A	F5327	981	BA4	C75
252	D82AB9	C3A187	C564A2	BA369	E763CF	435789	EC2865	D96721	D18468	B1234	A491	EF5327	981	5FC7	CE5
253	D982AB	C3A187	C564A2	EA3698	CF763	578943	5FC286	72196	DB4681	EB1234	D1AE49	F5327	B91	BA4	C75
254	D982AB	C3A187	C564A2	BA369	E763CF	578943	EC2865	72196	DB4681	4B123	D1A49	EF5327	B91	5FC7	CE5
255	DB982A	C3A187	C564A2	EBA369	CF763	578943	5FC286	72196	E4681B	D1234B	DA4E91	F5327	B1A	9B4	C75
256	DB982A	87C3A1	C564A2	9BA36	E763CF	894357	EC2865	96721	B4681	D12348	DA491	EF5327	B1A	5FC7	CE5
257	B982A	187C3A	C564A2	DA3698	E763CF	894357	EC2865	19672	81846	DB1234	D491A	EF5327	BA4	5FC7	CE5
258	E982CA	D5C187	EC564A	BA369F	D763C2	789435	D2865	96721	BF4681	E34B1C	4F91A	EA1253	752	AC3	984
259	B982CA	D75C18	E564AC	BA369F	EC2763	943578	D8652	D21967	BF4681	B1C34	A4F91	E3A125	728	C53	9B4
260	D4982A	EBA187	5F64AB	DA3691	C6F3B7	3F5C94	E28C5B	9C721	6C814	D12834	E753A2	89657	A41	782	563
261	D4982A	EBA187	564AB	DA3691	CF63B7	35FC94	E28C58	9C721	6C814	D12B34	E753A2	896F57	A41	7B2	C65
262	EC249D	87B41C	AF564B	B36912	A763F	578943	5AB286	C9672	D1468C	5F3B7	A3427	ED9821	E19C	DC1	A53
263	EC249D	87B41C	A564BF	B36912	A763	578943	5AB286	C9672	D1468C	53FB7	AF3427	ED9821	E19C	DC1	BA3
264	824659	875341	CB4256	BA6123	791632	AC3514	E9528F	DF7219	ED8157	BC64	CA43	AB36	EF89	D97F	8DE7
265	824659	875341	CB4256	BA6123	791632	AC3514	E95280	D7219	ED8157	BFC64	CFA43	AFB36	E789	D97	BCA
266	DC8249	84187	564BAF	2B3691	EA763F	578943	5AB286	C96721	D1468C	EF3B75	27A34	D981	C19	A5F	AE53
267	862935	653A91	BA2519	DB9ACF	781326	75218	856	7615	4B312A	C4923B	DCA394	EF4ABD	ECB4F	DFC	CED4