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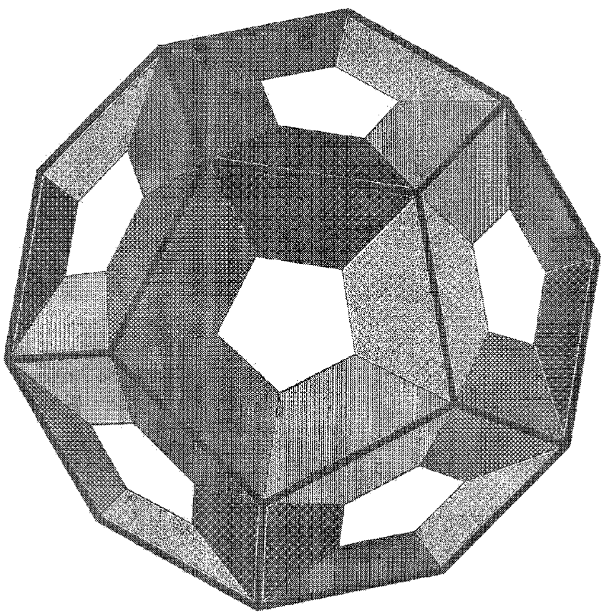

Figure 1

(57) Abstract: A three-dimensional polyhedra-form logic puzzle comprised of a plurality of independent, non-interconnected puzzle elements of three-dimensional geometric, axially-symmetric, pyramidal-peaked form including one or more apex-opposed polygon faces and a plurality of radial faces. Each edge of an apex-opposed face that contacts a radial face presents visible design indicia. Radial faces contain transversely-polarized magnetic, mechanical or electro-mechanical attachment mechanisms. The puzzle is solved and the three-dimensional polyhedra completed when puzzle elements are placed with the visible design indicia of every puzzle element's apex-opposed face edges conforming to those of every adjacent puzzle element. Radial faces may contain protuberances and cavities corresponding to indicia of corresponding apex-opposed face edges such that only puzzle elements with conforming apex-opposed face indicia will interjoin. Computerized processes determine viable solutions for indicia combinations on puzzle elements. Puzzle elements may be of pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar forms.

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LOGIC PUZZLE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to geometric logic puzzles characterized by independent, solid, three-dimensional, axially-symmetric, pyramidal-peaked puzzle elements, each of which puzzle elements has one or more apex-opposed polygonal faces bearing visible indicia. Each axially-symmetric, pyramidal-peaked puzzle element may be comprised of three-dimensional elements of pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar forms with radial faces of identical shape and size.

The goal of the puzzle is to assemble a pre-determined three-dimensional, solid geometric shape by placing the puzzle elements in an orientation with the apices of the pyramidal-peaked puzzle elements touching and with the edges of their apex-opposed faces also touching. The desired arrangement of the puzzle elements is such that the indicia of each of the edges of the visible apex-opposed polygonal faces of each puzzle element conforms to the indicia of the visible apex-opposed face edges of all adjacent puzzle elements. The visible indicia of such puzzles can be alphanumeric values, color elements, abstract patterns or geometric designs. In solving such puzzles, the most challenging ones are those that offer a number of apparently viable, nearly-completed solutions using many of the puzzle elements but which cannot be fully completed using the remaining puzzle elements. Only a select set of alignments of all of the puzzle elements – preferably just a single configuration – yield the completed assembly of the pre-determined geometric shape with full conformance of the visible indicia on the faces of the geometric puzzle elements.

This invention also relates to geometric logic puzzles that utilize analytical systems which may include computerized processes to determine combinations of indicia on the pyramidal-peaked puzzle elements resulting in viable, non-trivial, challenging solutions to the assembly of the pre-determined solid geometric shape. Finally, this invention relates to computerized manifestations and representations of three-dimensional polyhedra-type geometric logic puzzles with pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar forms of puzzle elements that are solved through interaction with computerized representations of these puzzle elements.

Description of the Prior Art

Puzzles have entertained and amused mankind for centuries. The present invention relates to geometric puzzles, logic puzzles and puzzles whose puzzle elements may be interjoined to form a single interconnected object.

Geometric puzzles can be as simple as two-dimensional tiles or three-dimensional building blocks. Alignment of the tiles or blocks can create larger geometric units of a predetermined shape.

Logic puzzles are designed and constructed with specifically delineated goals and operate within a framework of constraints on the available options. A puzzle solver uses logic to evaluate the typically interrelated constraints in order to ascertain the solution to the specified goal. A recently popular example of a logic puzzle is known as Sudoku. In a Sudoku puzzle, the goal is to fill a 9-by-9 grid with the numbers 1 through 9 while satisfying three constraints simultaneously. One constraint is that the nine 3-by-3 sub-grids cannot contain duplicate entries of the same number. The others are that neither any row nor any column through the whole grid can contain a duplicate entry of the same number. An initial Sudoku grid is partially filled with entries and the challenge for the puzzle solver is to logically evaluate the alternatives and find the single arrangement of missing numbers that fills all the remaining cells in a manner complying with the puzzle constraints.

Interconnecting blocks such as LEGO® are an indirect example of a puzzle where the puzzle elements may be interjoined to form a single interconnected object. The creation of a specific design – such as a sailing ship – using LEGO® constitutes a type of interjoining puzzle.

A geometric puzzle may exhibit the logic requirement while simultaneously using puzzle elements that may be interjoined. These characteristics are demonstrated in the well-known jigsaw puzzles, which have pictorial representations with repetitive or somewhat ambiguous visual patterns requiring logic to discern their placement. Such puzzle elements (jigsaw pieces) must satisfy both the visual indicators of the final pictorial representation and the physical requirements of the cutout designs necessary for interjoining with adjacent puzzle elements. When all the puzzle elements have been correctly placed, the full pictorial view is correctly presented and each puzzle element is physically interlocked with adjacent pieces into a single geometric object.

Geometric puzzles, logic puzzles and interjoining element puzzles have been the subject of numerous patented inventions. More than 125 years ago, U.S. Design Patent No. 4,793 (April 11, 1871) was issued to Samuel Loyd (1841 – 1911) for a logic puzzle that arranged eight distinctly-shaped, solid, three-dimensional puzzle elements to form a cube. Three-dimensional geometric puzzles typically offer the opportunity for the puzzle solver to interact with geometric solids where, by nature, only a part of the entire surface of the puzzle elements and/or of the final geometric construct are visible from a single vantage point. The puzzle solver must either physically or mentally rotate the geometric puzzle elements and/or completed geometric construct to evaluate alternative solutions to the puzzle.

One type of three-dimensional geometric puzzles offers the challenge of folding or otherwise manipulating a set of permanently interconnected components of a solid geometric shape into a configuration that satisfies specified conditions. These puzzles are characterized by multiple pieces that are permanently attached to one another at edges or other exterior points, allowing for folding or flexing the pieces within the constraint of the attachment mechanism. U.S. Pat. No. 2,992,829 discloses devices that are hinged along their edges and can be manipulated to create a variety of three-dimensional geometric solids. U.S. Pat. No. 4,323,244 discloses a solid geometrical puzzle comprised of a plurality of basic components that are hinged along two edges to neighboring components. U.S. Pat. No. 5,338,034 discloses a three-dimensional puzzle that includes multiple, permanently connected, irregular pyramids that are assembled into a regular tetrahedron. The apices of the irregular pyramids all meet at one point in the interior of the assembled tetrahedron and the bases of the irregular pyramids form the regular tetrahedron surfaces. U.S. Pat. No. 5,108,100 discloses a puzzle comprised of series of three-sided pyramids and eight-sided octaeder-shaped bodies interconnected between apex points by a string, the goal of the puzzle being to assemble the interconnected puzzle elements in a manner creating a large tetrahedon with uniformly colored sides.

A second type of three-dimensional geometric puzzles offers the challenge of rearranging interconnected but movable components of a solid geometric shape into a configuration that satisfies specified conditions. These puzzles are characterized by multiple pieces that are permanently attached to one another at interior points, allowing for shifting and rotating the pieces within the constraint of the attachment mechanism. Many of these puzzles provide the solver with the challenge of matching visible characteristics of the exposed surfaces but requires that the conformance be accomplished through a sequence shifts and rotations of the interconnected puzzle elements. Perhaps the best known puzzle of this type is Rubik's Cube®, the goal of which is to arrange the rotatable puzzle elements so that each cubic face is composed of puzzle elements of the same color. U.S. Pat. No. 3,655,201 discloses a pattern forming puzzle in the shape of a cube such that interconnected puzzle elements on the faces of the cube may be rotated to present uniformly colored faces on each side of the completed puzzle. Other examples of three-dimensional, rotational puzzles are disclosed in U.S. Pat. No. 4,378,116, U.S. Pat. No. 4,473,228, U.S. Pat. No. 4,474,376, U.S. Pat. No. 4,575,088 and U.S. Pat. No. 7,108,263. A variation of the rotational puzzle is disclosed in U.S. Pat. No. 4,416,453 in which only opposing faces of the polyhedron are interconnected and rotate in unison. U.S. Pat. No. 4,558,866 discloses a three-dimensional, rotational type, polyhedra-form logic puzzle with the solution goal of matching visible indicia. Puzzle elements are rotated to interchange their positions in the process of arriving at the solution to the puzzle.

A third type of three-dimensional geometric puzzles offers the challenge of assembling independent three-dimensional puzzle elements into a pre-determined solid geometric shape. The challenge of most such puzzles is finding the arrangements of puzzle elements that create the desired final structure. Loyd's Cube Puzzle is an example of this type of puzzle. U.S. Pat. No. 4,676,507 discloses a three-dimensional puzzle comprised of six identically-shaped puzzle elements that physically interconnect to create one of the five convex regular polyhedra generally known as the Platonic solids. A Platonic solid is a polyhedron all of whose faces are congruent regular convex polygons and where the same number of faces meets at every vertex.

U.S. Pat. No. 6,145,837 discloses a puzzle made of several three-dimensional puzzle elements that can be positioned to create several predetermined geometric shapes. U.S. Pat. No. 6,439,571 discloses a puzzle of cubic puzzle elements that have raised quadrants on some surfaces and flat quadrants on other surfaces such that the puzzle elements may be placed together to create a line, a square, a cube or a tesseract. U.S. Pat. No. 7,247,075 discloses a set of three-dimensional, rhombic-pyramid-shaped building blocks. U.S. Pat. App. Pub. No. US2005/0014112 A1 discloses a geometric solid entertainment system consisting of regular polygon, three-dimensional, pyramid-shaped building blocks.

Because independent three-dimensional puzzle elements offer multiple possible orientations in space, a fourth type of geometric puzzles creates solid three-dimensional shapes assembled by fitting together a number of smaller three-dimensional shapes while satisfying other, constraining conditions on the available alternative orientations of the puzzle elements. Such constraints allow the puzzle design to include the requirement to demonstrate specific characteristics such as matching the visible indicia or other physical attributes of adjacent puzzle elements. U.S. Pat. No. 3,565,442 discloses a puzzle composed of three-dimensional tetrahedral and octahedral puzzle elements to be arranged such that the visual indicia of die markings on the exterior faces are arranged to total the sum of thirteen on each face of the final polyhedron. U.S. Pat. No. 3,788,645 discloses a mathematical cube puzzle in which four separate cubes have on each of their edges one of three different colors. The object of the puzzle is to arrange the various cubes relative to one another such that the colors associated with all exposed adjacent playing edges of different cubes match one another. The puzzle has multiple solutions and the pieces can be arranged into a wide variety of different shapes. U.S. Pat. No. 4,210,332 discloses a pattern forming puzzle using independent puzzle elements with visible indicia on each face of the puzzle elements that are placed into a support structure in such a way that a predetermined pattern is created on each face of the final polyhedron. U.S. Pat. No. 4,258,479 discloses a puzzle with sets of right-triangular tetrahedron blocks, such sets being capable of assembly into cubes or pyramids exhibiting specified color schemes on the exterior faces. U.S. Pat. No. 4,865,324 discloses a three-dimensional puzzle comprised of a plurality of wheel-shaped puzzle elements along a common axis, the puzzle being solved when puzzle elements with matching visible indicia are placed in the correct order and rotated into alignment along that central axis. U.S.

Pat. No. 5,407,201 discloses a puzzle with multiple three-dimensional pieces of tetrahedral and square pyramidal form that feature indicia along their edges. When a three-dimensional geometric structure is correctly assembled from the pieces, completed indicia appear on all surfaces of the assembled geometric structure, with the portion of the indicia on each piece of the surface matching the complementary portion of the indicia on the adjacent surface. U.S. Pat. No. 5,411,262 discloses a puzzle with multiple, essentially two-dimensional puzzle elements that may be assembled to form a hollow three-dimensional object. U.S. Pat. No. 5,803,461 discloses a game in the form of a puzzle with two-dimensional or three-dimensional, identically-sized cubic puzzle elements marked by visible indicia. The goal of the game/puzzle is to align the puzzle elements such that the indicia match along adjacent edges while forming the geometric shape of a square. U.S. Pat. No. 6,257,574 discloses a multi-polyhedral puzzle of four tetrahedrons and a single octahedron that are fitted together in a transparent case in a manner such that abutting faces of adjacent polyhedron blocks form prescribed color patterns. U.S. Pat. No. 6,422,560 discloses a puzzle with multiple, three-dimensional cubic puzzle elements that may be assembled to form a three-dimensional cube with a distinct composite image on each face of the cube.

All four types of three-dimensional geometric puzzles described above require one or more processes to hold the puzzle elements together in the finished object. For the interconnected puzzles of the first type, direct physical connection is used to bind the pieces. A direct physical attachment mechanism is typically used for rotational-type puzzles although some variations, such as magnetic attachment, are suggested as in U.S. Pat. No. 4,558,866. Independent puzzle elements in puzzle types three and four are not bound by direct physical connection. Gravity in combination with friction is used in some designs as in U.S. Pat. No. 3,565,442. In other cases, the pieces are arranged in a separate support structure as in U.S. Pat. No. 4,210,332, U.S. Pat. No. 5,411,262 and U.S. Pat. No. 6,257,574. Magnetic mechanisms are used in a number of three-dimensional puzzles, as in U.S. Pat. No. 4,258,479, U.S. Pat. No. 5,411,262, U.S. Pat. No. 6,439,571, U.S. Pat. No. 7,247,075 and U.S. Pat. App. Pub. No. US2005/0014112 A1. Velcro, another releasable physical attachment mechanism, is proposed for securing pieces in place in U.S. Pat. App. Pub. No. US2005/0014112 A1.

Some of the three-dimensional puzzle inventions with independent puzzle elements disclose the use of the physical characteristics of the puzzle elements for assuring that adjacent puzzle elements are correctly aligned. U.S. Pat. No. 4,865,324 discloses that protuberances and cavities on the magnetic, wheel-shaped puzzle elements hold them in alignment in the direction of the axis so that visible indicia are precisely positioned to subsequently determine if the indicia are correctly matched. U.S. Pat. No. 6,439,571 discloses cubic puzzle elements that have raised quadrants on some surfaces and flat quadrants on other surfaces such that a raised quadrant will align and interlock with a flat quadrant and the linkage secured by magnetic bonding elements for the purpose of assembling the puzzle elements into the final configuration.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle 1) comprised of independent, three-dimensional, axially-symmetric, pyramidal-peaked shaped puzzle elements with clearly identifiable, identically-shaped radial faces that 2) exhibit design indicia on the edges of their visibly exposed faces and 3) all attaching radial faces of the puzzle elements contain transversely-polarized, magnetically attractive or other securing components such that 4) every properly aligned attaching radial face is identical in shape to and will be attracted to any other properly aligned attaching radial face and 5) that design indicia of every visibly exposed edge of every puzzle element must be correctly matched with its adjoining puzzle elements in order to successfully complete the puzzle. Further, none of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle that possesses physical characteristics on its attaching faces corresponding to the design indicia on the exposed faces such that only attaching faces with conforming visual indicia on exposed faces may be physically interjoined to successfully complete the puzzle. Radial faces of pyramidal-peaked puzzle elements are those faces that share a vertex point with the center of the complete polyhedron and an edge with the exterior of the complete polyhedron. Visibly exposed faces are those faces of the puzzle elements that do not share a vertex point with the center of the completed polyhedron and can be seen on the exterior of the completed polyhedron. The pyramidal-peaked puzzle elements are designed such that a clear orientation may be quickly established identifying all potential radial faces and visibly exposed faces for conformance of design indicia.

Further, none of the inventions described herein, nor any known or discovered, disclose a process for creating the arrangement of design indicia for a three-dimensional logic puzzle where the design indicia have been chosen such that all potential solutions to the puzzle for a given set of puzzle elements are known and can be evaluated to determine design indicia that yield a puzzle of desired difficulty, that difficulty being indicated by the number of potential solutions to the puzzle offered by the specific set of puzzle elements or by the number of partially completed puzzle configurations that cannot be successfully completed with the remaining puzzle elements. U.S. Pat. No. 5,407,201 discloses a logic puzzle with multiple three-dimensional puzzle elements of tetrahedral and square pyramidal form that feature indicia along their edges and includes a list of design indicia requirements for some puzzle element edges that must be met to assure that a solution does exist for the puzzle. However, because some of those puzzle elements may have multiple rotational orientations in all three dimensions, not all design indicia are matched with those of other puzzle elements either 1) because the indicia of the puzzle elements are hidden inside the completed geometric structure, 2) because the indicia of the puzzle elements are hidden inside the supporting base, or 3) because edge indicia of puzzle elements along the unbounded edge of the completed geometric structure are not constrained to match those of other puzzle elements. Thus, no process is disclosed for determining the appropriate design indicia for hidden or unbounded puzzle elements and no process is provided to assure that arbitrary assignment of those non-constrained design indicia won't yield a large number of alternative solutions to the puzzle making successful completion of the puzzle significantly less difficult than was expected. Further, no process is disclosed for determining the appropriate design indicia for puzzle elements used in a puzzle where every design indicia of every puzzle element visible on the exterior of the completed polyhedron is required to match the design indicia of every adjoining visible puzzle element.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle with independent, axially-symmetric, pyramidal-peaked puzzle elements wherein every radial face of the pyramidal-peaked puzzle elements is identical in shape to every other radial face and every properly aligned radial face possesses a transversely-polarized magnetic element that will magnetically attract any other radial face that is similarly aligned. Proper alignment of two pyramidal-peaked puzzle elements is achieved when the two of the identically-shaped radial faces of the puzzle elements are oriented so that vertices of the radial faces that both share the center of the completed polyhedron and edges of the radial faces that share the visibly exposed faces are aligned. Every known magnetically-attractive, three-dimensional geometric design using matching faces of three-dimensional puzzle elements exhibits the characteristic that a given face contains a magnet with one of two possible polarities. Thus, for any specific polarity, some puzzle elements will be attracted and others will not. For instance, in U.S. Pat. No. 7,247,075 a left triangular face is designed to attract and attach only to a right triangular face. U.S. Pat. No. 5,411,262 discloses in Fig. 7 an arrangement of magnets along the edges of essentially two-dimensional puzzle elements that causes any edge of any puzzle element to be attracted to any edge of another puzzle element. However, if one of the puzzle elements is flipped over – an apparently allowable potential alignment for the two-dimensional puzzle elements – then none of its edges are attracted to any of the edges of other puzzle elements.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle with independent, axially-symmetric, pyramidal-peaked puzzle elements wherein every radial face of the pyramidal-peaked puzzle elements – relative to the apex of the pyramid – is readily identifiable and distinguished from its base face and is identical in shape to every other radial face of the other puzzle elements. For instance, in U.S. Pat. No. 7,247,075 some of the radial faces of the axially-asymmetric pyramidal elements are referred to as left triangular faces whereas others are described as right triangular faces. U.S. Pat. No. 5,407,201 discloses a logic puzzle with multiple three-dimensional puzzle elements of tetrahedral and square pyramidal form, with many of the triangular faces of identical shape. However, the tetrahedral puzzle elements do not present identifiable radial faces that can be readily distinguished relative to a discernable apex from the other faces of the puzzle elements.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle assuring that only attaching faces of puzzle elements with conforming visual indicia may be physically interjoined. The arrangement of protuberances and cavities on the connecting edges of the puzzle elements disclosed in U.S. Pat. No. 4,865,324 are designed for the sole purpose of assuring that visible design indicia on the exterior edges of the wheel-shaped puzzle elements are presented in a limited number of distinct alignments rather that offering a nearly unlimited combination of alignment possibilities that would result if the puzzle elements turned without restriction. The physical nature of the protuberances and cavities as disclosed do not, however, prevent puzzle elements with non-matching visible indicia from being placed and connected to one another.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle such that every edge of every apex-opposed face of every puzzle element must be correctly matched with the edges of apex-opposed faces of the adjoining puzzle elements in order to successfully complete the puzzle. U.S. Pat. No. 5,407,201 discloses a puzzle with independent three-dimensional puzzle elements that requires matching visible indicia along the edges of the puzzle elements. However, many of the edges of puzzle elements in that puzzle are not constrained to match with the edges of any other puzzle elements. These unmatched edges are either hidden inside the completed three-dimensional structure (including the supporting base) or sit on the unbounded exterior of the completed structure.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle such that every puzzle element is of three-dimensional dipyramidal shape -- as though two pyramidal shaped puzzle elements had been securely joined over their base faces -- with the dipyramidal puzzle elements still offering recognizable radial faces to be interjoined based on conformance between the visibly exposed faces of the other halves of the dipyramidal puzzle elements.

None of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle such that every puzzle element is of three-dimensional trapezohedral shape -- consisting of identical deltoid faces -- with the trapezohedral puzzle elements offering recognizable radial faces to be interjoined based on conformance between the visibly exposed faces of the other halves of the trapezohedral puzzle elements.

Finally, none of the inventions described herein, nor any known or discovered, disclose a design for a three-dimensional logic puzzle such that every puzzle element is of three-dimensional rhombohedric shape – consisting of identical parallelogram faces– with the rhombohedric puzzle elements still offering recognizable apices distinguishing the orientation of the radial faces to be interjoined based on conformance between the visibly exposed faces of the other halves of the rhombohedric puzzle elements.

SUMMARY OF THE INVENTION

The present invention discloses a geometric logic puzzle characterized by independent, solid, three-dimensional, axially-symmetric, pyramidal-peaked puzzle elements constructing a completed polyhedra with visible indicia on the apex-opposed, exposed faces of each puzzle element and conditions specified for placement of the puzzle elements such that visual indicia on adjacent puzzle elements satisfy certain constraints. Axially-symmetric, pyramidal-peaked puzzle elements – of pyramidal, dipyramidal, trapezohederal, rhombohedric or other similar form – are those puzzle elements that exhibit a plurality of identically-shaped, flat faces angled such that the faces converge at a peak associated with an apex and such that the appearance of the puzzle element is identical for a face-to-face rotation around the central axis passing through the apex.

A regular pyramid is the pyramidal-peaked polyhedron formed by joining an apex-opposed regular polygonal base face to the apex with triangular radial faces. An apex-opposed face is a face of a polyhedron that does not contact that apex. For axially-symmetric, pyramidal-peaked puzzle elements, every face of the puzzle element either contacts a given apex as a radial face or is opposed to that apex. A dipyramid is the double-pyramidal-peaked polyhedron formed by joining a regular pyramid and its mirror image base-to-base making the apex-opposed faces those radial faces of the opposite apex. A trapezohedron is the double-pyramidal-peaked polyhedron formed by joining uniform deltoids. A rhombohedron is a special case of a trapezohedron for which the double-pyramidal-peaked polyhedron is formed by joining uniform parallelograms.

As a puzzle solver selects puzzle pieces to adjoin each other and selects which faces of those pieces to align facing each other in the completed puzzle, a face of one puzzle piece can be releasably attached to an adjacent face of an adjoining puzzle piece by a number of possible attachment mechanisms. The pyramidal-peaked puzzle elements may contain transversely-polarized magnetic, mechanical or electro-mechanical attachment mechanisms on or inside each radial face aligned to secure two conforming radial faces when they are placed together. If it is determined that two puzzle pieces do not properly fit next to each other in the completed puzzle, the pieces can easily be disengaged from each other to allow other configurations to be attempted.

Each radial face of each puzzle element can beneficially exhibit physical characteristics corresponding with the indicium on the edge of the apex-opposed face shared by the radial face. Such a radial face may contain patterns of protuberances and cavities arranged such that it interjoins with a conforming radial face of another puzzle element – and thereby conforming edges of apex-opposed faces on the two puzzle elements – when the puzzle elements are placed together. The patterns of protuberances and cavities prevent interjoining when two puzzle elements with non-conforming radial faces – and thereby non-conforming edges of apex-opposed faces – are placed together.

This invention discloses as an example the specific geometric logic puzzles characterized by independent, solid, three-dimensional, axially-symmetric, pyramidal puzzle elements with visible indicia on each edge of each identically-shaped base face of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. Each edge of each regular polygonal base face of each pyramidal puzzle element expresses visible design indicium that can be an alphanumeric value, a color element, an abstract pattern, a geometric design or a combination of the alternatives. By way of example, pyramidal puzzle elements possess a single distinct apex point and a single, apex-opposed, regular polygonal base face. Thus, pyramidal puzzle elements may be oriented in a single distinct direction wherein the sets of triangular radial faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the apex-opposed base faces are visibly exposed on the exterior of the completed polyhedron. The pyramidal puzzle elements contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each triangular radial face aligned to secure two conforming triangular faces when they are placed together. The three-dimensional polyhedra with conforming indicia on both sides of each exposed base face edge results when all pyramidal puzzle elements with conforming triangular radial faces are properly aligned and interjoined.

This invention also discloses as an example the specific geometric logic puzzles characterized by independent, solid, three-dimensional, axially-symmetric, dipyramidal puzzle elements with visible indicia on each identically-shaped triangular face of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. Each triangular face of each dipyramidal puzzle element expresses visible design indicium that can be an alphanumeric value, a color element, an abstract pattern, a geometric design or a combination of the alternatives. Dipyramidal puzzle elements consisting of only triangular faces are distinguished from pyramidal puzzle elements by possessing two distinct apex points instead of just one and by having no base face. Thus, dipyramidal puzzle elements may be oriented in two distinct directions wherein 1) one set of triangular faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other triangular faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously exposed and visible faces are instead placed at the center of the complete polyhedron and the previously interior triangular faces are visibly exposed on the exterior of the completed polyhedron. The dipyramidal puzzle elements beneficially contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each triangular face aligned to secure two conforming triangular faces when they are placed together. The three-dimensional, stellated polyhedra with conforming indicia on both sides of each exposed central edge results when all dipyramidal puzzle elements with conforming triangular faces are aligned and interjoined.

A central edge is an edge of the three-dimensional dipyramidal puzzle element that does not contact either apex. As with the pyramidal puzzle elements, each triangular face can exhibit physical characteristics corresponding with the indicium on its opposing-edged triangular face. An opposing-edged triangular face is that face of the dipyramidal puzzle element with which the initial triangular face shares a central edge and which face is connected to the opposing apex. The physical characteristics of each triangular face can consist of patterns of protuberances and cavities aligned such that the face of a puzzle element interjoins with the triangular face of another puzzle element when conforming opposing-edged triangular faces of the two puzzle elements are placed together at their central edge. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two puzzle elements with non-conforming opposing-edged triangular faces together.

The completed polyhedra of this invention created from dipyramidal puzzle elements are referred to as stellated, or star-like, forms although they may not be identical to the geometrically-defined stellated form since the dipyramidal puzzle elements need not strictly exhibit the extension of internal faces or edges. The completed polyhedra that may be created from dipyramidal puzzle elements include stellated versions of the Platonic solids, the Archimedean solids, and other uniform and non-uniform polyhedra.

This invention also discloses as an example the specific geometric logic puzzles characterized by independent, solid, three-dimensional, axially-symmetric, trapezohedral puzzle elements with visible indicia on all identically-shaped deltoidal (kite-shaped) faces of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. Each deltoidal face of each trapezohedral puzzle element expresses visible design indicium that can be an alphanumeric value, a color element, an abstract pattern, a geometric design or a combination of alternatives. Trapezohedral puzzle elements are distinguished from pyramidal and dipyramidal puzzle elements by possessing only deltoidal faces but like dipyramidal puzzle elements they possess two distinct apex points and no base face. Thus, trapezohedral puzzle elements may be oriented in two distinct directions wherein 1) one set of deltoidal faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other deltoidal faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously exposed and visible faces are instead placed at the center of the complete polyhedron and the previously interior deltoidal faces are visibly exposed on the exterior of the completed polyhedron. The trapezohedral puzzle elements contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each deltoidal face aligned to secure two conforming deltoidal faces when they are placed together. The three-dimensional polyhedra with conforming indicia on both sides of each exposed central edge results when all trapezohedral puzzle elements with conforming deltoidal faces are aligned and interjoined. The completed polyhedra that may be created from trapezohedral puzzle elements include alternately-stellated versions of the Platonic solids, the Archimedean solids, and other uniform and non-uniform polyhedra

A central edge is an edge of the three-dimensional trapezohedral puzzle element that does not contact either apex. As with the pyramidal and dipyramidal puzzle elements, each deltoidal face can exhibit physical characteristics corresponding with the indicium on its two opposing-edged deltoidal faces. Opposing-edged deltoidal faces are those two faces of the trapezohedral puzzle element with which the initial deltoidal face shares a central edge and which faces are connected to the opposing apex. The physical characteristics of each deltoidal face can consist of patterns of protuberances and cavities aligned such that the face of a puzzle element interjoins with the deltoidal face of another puzzle element when conforming opposing-edged deltoidal faces of the two puzzle elements are placed together along their central edges. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two puzzle elements with non-conforming opposing-edged deltoidal faces together.

This invention also discloses as an example the specific geometric logic puzzles characterized by independent, solid, three-dimensional, axially-symmetric, rhombohedric puzzle elements with visible indicia on all identically-shaped parallelogram faces of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. Each parallelogram face of each rhombohedric puzzle element expresses visible design indicium that can be an alphanumeric value, a color element, an abstract pattern, a geometric design or a combination of alternatives. Rhombohedric puzzle elements are distinguished from pyramidal and dipyramidal puzzle elements by possessing only parallelogram faces but like dipyramidal puzzle elements they possess two distinct apex points and no base face. Thus, rhombohedric puzzle elements may be oriented in two distinct directions wherein 1) one set of parallelogram faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other parallelogram faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously exposed and visible faces are instead placed at the center of the complete polyhedron and the previously interior parallelogram faces are visibly exposed on the exterior of the completed polyhedron. The rhombohedric puzzle elements ideally contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each parallelogram face aligned to secure two conforming parallelogram faces when they are placed together. The three-dimensional polyhedra with conforming indicia on both sides of each exposed central edge results when all rhombohedric puzzle elements with conforming parallelogram faces are properly aligned and interjoined. The completed polyhedra that may be created from rhombohedric puzzle elements include the rhombic hexecontahedron.

A central edge is an edge of the three-dimensional rhombohedric puzzle element that does not contact either apex. As with the pyramidal and dipyramidal puzzle elements, each parallelogram face can exhibit physical characteristics corresponding with the indicium on its two opposing-edged parallelogram faces. Opposing-edged parallelogram faces are those two faces of the rhombohedric puzzle element with which the initial parallelogram face shares a central edge and which faces are connected to the opposing apex. The physical characteristics of each parallelogram face can consist of patterns of protuberances and cavities aligned such that the face of a puzzle element interjoins with the parallelogram face of another puzzle element when conforming opposing-edged parallelogram faces of the two puzzle elements are placed together along their central edges. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two puzzle elements with non-conforming opposing-edged parallelogram faces together.

This invention discloses the use of transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside the attaching faces of each three-dimensional, axially-symmetric, pyramidal-peaked puzzle element so that any puzzle element that is correctly aligned with an adjoining puzzle element is secured to complete the final polyhedra and yields a three-dimensional object that can be rotated, examined and handled without the constraint of a supporting base or structure.

This invention discloses the use of physical characteristics on the attaching faces of each puzzle element consisting of patterns of protuberances and cavities such that only properly aligned puzzle elements with conforming visible indicia on the exposed faces may be successfully interjoined. Those patterns of protuberances and cavities prevent interjoining when an attempt is made to place the properly aligned faces of two non-conforming puzzle elements together.

The development of an analytical solution determination process that evaluates the possible configurations of indicia on a set of puzzle elements is a significant component of the invention. Some configurations of indicia yield multiple solutions while other configurations yield no solutions. For example, if every edge of every puzzle element were to contain the same indicium, any puzzle element could be interjoined with any other puzzle element in any rotational alignment, making the solution of the puzzle extremely trivial. Conversely, if every edge of every puzzle element were to contain a distinct indicium, then no two puzzle elements could ever be combined, making no solution possible whatsoever. The more challenging configurations of indicia on the puzzle elements 1) would contain the same indicium on the edges of many of the puzzle elements, 2) would use a combination of indicia on the exposed face of each puzzle element that was distinct from the combination on any other puzzle element, and 3) would choose the set of puzzle elements such that a limited arrangement of aligned puzzle elements yielded the correct solution to the puzzle. For the most difficult configuration, successful placement of each puzzle element would be interdependent on the correct placement of every other puzzle element, yielding just a single solution to completion of the puzzle.

This invention discloses a plurality of three-dimensional polyhedra that are used for the completed puzzle. Many of the final polyhedra resulting as solutions for the puzzles of this invention contain so many faces and edges that the choice of indicia configurations for the puzzle elements is a difficult task. This invention discloses an analytical solution determination process that can be effectively implemented by computerized techniques to determine combinations of indicia on any given set of puzzle elements that result in viable, non-trivial solutions to the assembly of the pre-determined solid polyhedral shape.

In addition, an evaluation process is disclosed to evaluate the number of decision steps required in determining the arrangement of puzzle elements yielding a viable solution to the puzzle. In solving the puzzle, a number of conforming alignments that offer apparently viable partial solutions may be found that employ some – but not all – of the puzzle elements. Many of those partial solutions cannot be brought to completion using the remaining puzzle elements. A final solution can only be found from a select set of alignments of all of the puzzle elements. The greater the number of partial solutions offered by the configuration of indicia on the puzzle elements, the greater the number of decision steps (on average) that are required to determine a solution to the puzzle. The measure of the number of potential decision steps provides a strong indicator of the challenge involved in solving the puzzle.

This invention discloses the use of visual indicia on the pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar puzzle elements. In some implementations, the visual indicia may be a compounded form of two or more types of indicia (such as abstract patterns placed in a background of color elements) with each type of indicia chosen in such a way as to represent a distinct puzzle. A single set of such puzzle elements can be used to provide two or more distinctly different puzzle solving challenges with distinctly different levels of difficulty.

Finally, this invention discloses that computerized manifestations and representations of the three-dimensional, polyhedra-type, geometric logic puzzles of this invention with pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar puzzle elements can be used to solve the puzzles of this invention through human interaction with computerized representations of the puzzle elements.

OBJECTIVES AND ADVANTAGES OF THE INVENTION

The present invention discloses a logic puzzle of three-dimensional polyhedra-form consisting of independent, three-dimensional, axially-symmetric, pyramidal-peaked puzzle elements with the puzzle elements of the required dimensions and present in the exact number necessary and sufficient to construct a predetermined three-dimensional polyhedron. The objective of the puzzle is to position the puzzle elements relative to each other in a way that satisfies specified conditions on the relationships of adjacent visual indicia on the visible portions of adjoining puzzle elements. For every particular manifestation of this puzzle, all connecting radial faces of all puzzle elements for a specified polyhedron have exactly the same dimensions making every radial face identical in shape and size. Thus, each puzzle element presents an identical physical shape over a series of rotations around the central axis of the pyramidal-peaked puzzle element (i.e., axially-symmetric), the number of identical appearances equal to the number of radial faces of the puzzle element. Puzzle elements can be of pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar form with identical triangular, deltoidal, parallelogrammatic or other radial faces, respectively. Each radial face of each puzzle element beneficially contains transversely-polarized magnetic, mechanical or electro-mechanical attachment components on or inside that face so that any puzzle element that is correctly aligned with an adjoining puzzle element is secured to complete the final polyhedra. The radial faces of the puzzle elements can also exhibit physical characteristics consisting of patterns of protuberances and cavities such that only properly aligned puzzle elements with conforming visible indicia on the exposed faces may be successfully interjoined and those puzzle elements with non-conforming visual indicia may not be successfully interjoined.

The objective of the disclosed invention is to provide an interesting, challenging, enjoyable, educational, entertaining, and visually appealing puzzle that can be solved by a wide range of puzzle enthusiasts by offering a range of complexity from relatively easy to very difficult. This invention also offers tactile and visual interaction with the three-dimensional puzzle elements and completed object.

An advantage of these requirements is that a very large number of combinations of placements of a set of puzzle elements are possible in constructing the finished polyhedron. Using twelve 5-pyramid puzzle elements (having a regular pentagon as the base face of the pyramidal puzzle element) to construct a twelve-sided dodecahedron and starting with any one of the puzzle elements, there are 1,949,062,500,000,000 (about 2 quadrillion) possible positional and rotational arrangements of the eleven remaining puzzle elements. This result is the product of five (5) to the eleventh (11^{th}) power times eleven factorial (11!). The large number of combinations makes this puzzle potentially very challenging but the constraining conditions on the conforming of visual indicia on the puzzle elements limits the number of those combinations that successfully solve the puzzle. The puzzle solver must use logical deduction and inference regarding the constraining conditions and the available puzzle elements to effectively solve the puzzle because the process of random selection and placement of puzzle elements would be essentially futile in finding a successful solution to the puzzle. The process of discovering a single solution from the vast number of possibilities gives the puzzle solver a significant sense of accomplishment.

An alternative implementation of this invention using twenty 3-pyramid puzzle elements to construct a twenty-sided icosahedron has 1.4×10^{26} (about 140 septillion) possible positional and rotational arrangements of the nineteen puzzle elements that remain after arbitrarily choosing one puzzle element as the starting point.

A further object of the invention is to provide axially-symmetric, pyramidal-peaked puzzle elements containing attachment mechanisms, such as transversely-polarized magnets, so that appropriately aligned puzzle elements may be interjoined over their conforming radial faces and the partially completed polyhedron may be rotated, examined and evaluated to determine the subsequent choices of puzzle elements for placement in attempting to complete the puzzle. The attachment mechanisms beneficially offer the advantage that the completed polyhedron is self-supporting and needs no framework or other structural components to maintain its final shape. Ideal attachment mechanisms allow for easy release of puzzle elements which have been placed adjacent to each other, to allow for new placement of puzzle elements if an attempted arrangement is not successful.

A further possible object of the invention is to provide axially-symmetric, pyramidal-peaked puzzle elements which exhibit physical characteristics on the radial faces such as patterns of protuberances and cavities corresponding to the visual indicia on the base face edges to which the radial faces are attached such that only two puzzle elements with conforming visual indicia on the edges of their exposed faces may be successfully interjoined on their corresponding radial faces, providing a physical indication and confirmation of the successful conforming of the visual indicia of the puzzle elements.

A further object of this invention is to provide pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar form puzzle elements which may be used to create convex polyhedra such as the dodecahedron, stellated polyhedra with triangular faces such as the stellated dodecahedron, alternately-stellated polyhedra with deltoidal faces, stellated polyhedra with parallelogrammatic faces, and other various polyhedra that present completed puzzles with distinct and appealing appearances.

This invention discloses a plurality of three-dimensional polyhedra that can be used for the completed object of the puzzle; many of these polyhedra contain many faces and edges making the selection of indicia configurations for the puzzle elements a difficult task. An advantage of this invention is that an analytical solution determination process is disclosed that can be used to determine the patterns of visual indicia on a set of puzzle elements, assuring that the constraints specified by the puzzle conditions (e.g., conforming edges) can be met and that a solution to the puzzle is possible. Another advantage is that a disclosed evaluation process can be used to estimate the difficulty in completing the puzzle for any given set of puzzle elements, permitting the design of puzzles of various levels of difficulty.

Another advantage of this invention is that the visual indicia of the pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar form puzzle elements may be compounded to allow for multiple expressions of alphanumeric values, color elements, abstract patterns or geometric designs in such a way that each type of expression of indicia represents a distinct puzzle. Thus, a single set of puzzle elements can be used to provide two or more distinctly different puzzle solving challenges with distinctly different levels of difficulty.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a front-side view of a completed dodecahedron with edges presenting conforming indicia of shading patterns.

FIG. 2 shows a set of detailed views of a completed dodecahedron with numbered faces and with edges presenting conforming indicia of shading patterns. FIG. 2a is the front view, FIG. 2b is the back view, FIG. 2c is the top view and FIG. 2d is the bottom view.

FIG. 3 shows a set of detailed views of a 5-pyramidal puzzle element. FIG. 3a shows the base face with lower case alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 3b shows a side view of the 5-pyramidal puzzle element with arrows showing the locations of lower case alphabetic-labeled edges on the obscured bottom base face.

FIG. 4 shows the base face of a 5-pyramid puzzle element with the shading pattern indicia labeled with upper case letters.

FIG. 5 shows a flat view of a dodecahedron with the numbered faces showing lower case alphabetic-labeled edges and the sequence of faces progressing around the first face outward in a clockwise direction.

FIG. 6 shows a flat view of a completed dodecahedron with the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a solution to a puzzle for that set of indicia combinations.

FIG. 7 shows a flat view of a completed dodecahedron with the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a solution to a puzzle for a different set of indicia combinations.

FIG. 8 shows a flat view of a partially completed dodecahedron with the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a partial solution to a puzzle with a different arrangement of the same indicia combinations as in FIG. 7.

FIG. 9 shows a table format of the numbered faces showing lower case alphabetic-labeled adjacent edges that are located between faces corresponding to arrangement of FIG 5.

FIG. 10 shows a table format of the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a solution to a puzzle for the set of indicia combinations of FIG 6.

FIG. 11 shows a table format of the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a solution to a puzzle for the set of indicia combinations of FIG 7.

FIG. 12 shows a table format of the numbered faces showing upper case alphabetic-labeled indicia combinations that provide a partial solution to a puzzle for the set of indicia combinations in the arrangement of FIG 8.

FIG. 13 shows a set of detailed views of transversely-polarized magnetic attachment mechanisms on the radial faces of a 5-pyramidal puzzle element. FIG 13a shows the view looking down on the puzzle element from above the apex. FIG 13b shows a side view of the 5-pyramidal puzzle element.

FIG. 14 shows a flat view of the arrangement of transversely-polarized attachment mechanisms on the radial faces of six 5-pyramidal puzzle elements.

FIG. 15 shows a set of detailed views of protuberances and cavities on a radial face of a pyramidal puzzle element. FIG 15a shows a view of the radial face looking down on the puzzle element from above radial face. FIG 15b shows a view of the radial face looking at the puzzle element from the base face end of the radial face. FIG 15c shows a view of the radial face looking at the puzzle element from the side of the radial face. FIG 15d shows a pair of conforming faces with widely-spaced, matching protuberances and cavities viewed from the base face end of the radial face. FIG 15e shows a pair of conforming faces with widely-spaced, matching protuberances and cavities viewed from the side of the radial face. FIG 15f shows a pair of conforming faces with centrally-spaced, matching protuberances and cavities viewed from the base face end of the radial face. FIG 15g shows a pair of conforming faces with narrowly-spaced, matching protuberances and cavities viewed from the base face end of the radial face.

FIG. 16 shows a side view of the protuberances and cavities in conjunction with transversely-polarized attachment mechanisms on the radial faces of a 5-pyramidal puzzle element.

FIG. 17 shows a set of detailed views of a 3-pyramidal puzzle element. FIG. 17a shows the base face with alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 17b shows a side view of the 3-pyramidal puzzle element with arrows showing the locations of alphabetic-labeled edges on the obscured bottom base face.

FIG. 18 shows a flat view of an icosahedron with the numbered faces showing lower case alphabetic-labeled edges and progressing around the first face outward in a clockwise direction.

FIG. 19 shows a set of detailed views of a 4-pyramidal puzzle element. FIG. 19a shows the base face with alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 19b shows a side view of the 4-pyramidal puzzle element.

FIG. 20 shows a set of detailed views of a 6-pyramidal puzzle element. FIG.20a shows the base face with alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 20b shows a side view of the 6-pyramidal puzzle element.

FIG. 21 shows a set of detailed views of an 8-pyramidal puzzle element. FIG. 21a shows the base face with alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 21b shows a side view of the 8-pyramidal puzzle element.

FIG. 22 shows a set of detailed views of a 10-pyramidal puzzle element. FIG. 22a shows the base face with alphabetic-labeled edges progressing around the face in a clockwise direction. FIG. 22b shows a side view of the 10-pyramidal puzzle element.

FIG. 23 shows a front-side view of a completed stellated dodecahedron constructed using 5-dipyramidal puzzle elements with exposed radial faces presenting conforming indicia of shading patterns.

FIG. 24 shows a set of detailed views of a 5-dipyramidal puzzle element. FIG. 24a shows a transparent side view of the 5-dipyramidal puzzle element. FIG. 24b shows a side view of the 5-dipyramidal puzzle element with alphabetic-labeled radial faces progressing around the puzzle element in a clockwise direction when viewed from the apices.

FIG. 25 shows a side view of the transversely-polarized magnetic attachment mechanisms on the radial faces of a 5-dipyramidal puzzle element.

FIG. 26 shows a side view of the protuberances and cavities on the radial faces of a 5-dipyramidal puzzle element.

FIG. 27 shows a side view of the protuberances and cavities in conjunction with transversely-polarized attachment mechanisms on the radial faces of a 5-dipyramidal puzzle element.

FIG. 28 shows a set of detailed views of a 3-dipyramidal puzzle element. FIG. 28a shows a transparent side view of the 3-dipyramidal puzzle element. FIG. 28b shows a side view of the 3-dipyramidal puzzle element with alphabetic-labeled radial faces progressing around the puzzle element in a clockwise direction when viewed from the apices.

FIG. 29 shows a transparent side view of a 4-dipyramidal puzzle element.

FIG. 30 shows a transparent side view of a 6-dipyramidal puzzle element.

FIG. 31 shows a transparent side view of an 8-dipyramidal puzzle element.

FIG. 32 shows a transparent side view of a 10-dipyramidal puzzle element.

FIG. 33 shows a front-side view of a completed alternately stellated dodecahedron constructed using 5-trapezohedral puzzle elements with each half of every exposed deltoid face presenting shading pattern indicia conforming to that of the deltoid face of the adjacent puzzle element.

FIG. 34 shows a set of detailed views of a 5-trapezohedral puzzle element. FIG. 34a shows a transparent side view of the 5-trapezohedral puzzle element. FIG. 34b shows a side view of the 5-trapezohedral puzzle element with alphabetic-labeled radial face indicia pairs progressing around the puzzle element in a clockwise direction when viewed from the apices.

FIG. 35 shows a flat view of a stellated dodecahedron with the numbered radial face indicia pairs showing lower case alphabetic-labeled edges.

FIG. 36 shows a side view of the transversely-polarized attachment mechanisms on the radial faces of a 5-trapezohedral puzzle element.

FIG. 37 shows a side view of the protuberances and cavities on the radial faces of a 5-trapezohedral puzzle element.

FIG. 38 shows a side view of the protuberances and cavities in conjunction with transversely-polarized attachment mechanisms on the radial faces of a 5-trapezohedral puzzle element.

FIG. 39 shows a front-side view of a completed rhombic hexecontahedron with each half of every exposed parallelogram face presenting shading pattern indicia conforming to that of the parallelogram face of the adjacent puzzle element.

FIG. 40 shows a set of detailed views of a rhombohedric puzzle element. FIG. 40a shows a shaded, horizontal side view of the rhombohedric puzzle element. FIG. 40b shows a quasi-transparent view of the rhombohedric puzzle element from above an apex of the puzzle element. FIG. 40c shows a quasi-transparent, vertical side view of the rhombohedric puzzle element.

FIG. 41 shows a set of detailed views of a rhombohedric puzzle element with each half of every exposed parallelogram face presenting shading pattern indicia. FIG. 41a shows a view of two of the exposed parallelogram faces of the rhombohedric puzzle element presenting shading pattern indicia as seen from above an apex of the puzzle element. FIG. 41b shows a vertical side view of three of the exposed parallelogram faces of the rhombohedric puzzle element presenting shading pattern indicia. FIG. 41c shows a view of an exposed parallelogram faces of the rhombohedric puzzle element presenting shading pattern indicia as seen from below the alternate apex of the puzzle element.

FIG. 42 shows a set of detailed views of a rhombohedric puzzle element with each half of every exposed parallelogram face presenting alphabetic-labeled indicia. FIG. 42a shows a view of the parallelogram faces of the rhombohedric puzzle element presenting alphabetic-labeled indicia as seen from above an apex of the puzzle element. FIG. 42b shows a vertical side view of three of the exposed parallelogram faces of the rhombohedric puzzle element presenting alphabetic-labeled indicia. FIG. 42c shows a view of the parallelogram faces of the rhombohedric puzzle element presenting alphabetic-labeled indicia as seen from below the alternate apex of the puzzle element.

FIG. 43 shows a flat view of an icosahedron-like rhombic hexecontahedron puzzle with each numbered puzzle element showing one set of alphabetic-labeled edges and progressing around the first puzzle element outward in a clockwise direction.

FIG. 44 shows a side view of the protuberances and cavities on the parallelogram faces of a rhombohedric puzzle element.

FIG. 45 shows a side view of the protuberances and cavities in conjunction with transversely-polarized magnetic attachment mechanisms on the parallelogram faces a rhombohedric puzzle element.

FIG. 46 shows a flat view of an octahedron.

FIG. 47 shows a flat view of a cuboctahedron.

FIG. 48 shows a flat view of a small rhombicuboctahedron.

FIG. 49 shows a flat view of an icosidodecahedron.

FIG. 50 shows a flat view of a rhombicosidodecahedron.

FIG. 51 shows a flat view of a truncated icosahedron.

FIG. 52 shows a flat view of a great rhombicuboctahedron.

FIG. 53 shows a flat view of a rhombitruncated icosidodecahedron .

FIG. 54 shows a detailed view of the base face of a 5-pyramidal puzzle element with two distinct sets of indicia.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention discloses a three-dimensional polyhedra-form logic puzzle consisting of a plurality of independent, non-interconnected puzzle elements that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. Each puzzle element is a solid, three-dimensional geometric, axially-symmetric, pyramidal-peaked form that includes one or more apex-opposed polygon faces and a plurality of identical-shaped radial faces, each of which puzzle elements has one or more apex-opposed polygonal faces bearing visible indicia. Each axially-symmetric, pyramidal-peaked puzzle element may be comprised of three-dimensional elements of pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar forms with radial faces of identical shape and size. Much of the discussion herein will refer to the three-dimensional puzzle elements as pyramidal, having a polyhedron for a base, triangular radial faces and a single, common vertex shared by all of the radial faces in an axially-symmetric manner. Alternative examples of axially-symmetric, pyramidal-peaked puzzle elements using dipyramidal, trapezohedral and rhombohedric forms will also be provided. It is understood that the particular shape and size of each puzzle element, each apex-opposed face and each radial face may vary, as long as the puzzle elements in a particular puzzle have radial faces that are of like shape and size. Thus, each reference to a particular shaped element, apex-opposed face or radial face is intended to be an example and not limiting. As a specific example, a single, square, apex-opposed face would yield an axially-symmetric 4-pyramid with a square base – the commonly recognized Egyptian pyramid form – while a single, regular, pentagonal base face would yield an axially-symmetric 5-pyramid.

Each edge of each apex-opposed face of each puzzle element expresses at least one visible design indicium that can be an alphanumeric value, a color element, an abstract pattern, a geometric design or some combination of these alternatives. The pyramidal-peaked puzzle elements beneficially contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each radial face aligned to secure two matching radial faces when they are placed together.

The three-dimensional polyhedra with matching indicia on both sides of each exposed visible edge results when all pyramidal-peaked puzzle elements with matching radial faces are aligned and interjoined. Pyramidal-peaked, axially-symmetric puzzle elements can be of pyramidal, dipyramidal, trapezohedral, rhombohedric or other similar forms. The completed polyhedra that can be created from a specifically-proportioned set of pyramidal-peaked puzzle elements include – but are not limited to – the Platonic solids (such as the dodecahedron and the icosahedron); the Archimedean solids (such as the cuboctahedron and the rhombicosidodecahedron); other uniform polyhedra such as the rhombic hexecontahedron and the ditrigonal icosidodecahedron; non-uniform polyhedra such as the elongated square gyrobicupola; a number of convex rhombic polyhedra such as the rhombic dodecahedron; and stellated and alternately-stellated versions of many of these polyhedra. Examples of polyhedra that may be formed upon completion of a puzzle are shown in Figures 46 – 53.

A variety of constraining conditions which must be satisfied to complete the puzzle are possible. In the preferred embodiment, the solution to the puzzle is the assembly of a pre-determined three-dimensional, solid polyhedron by placing pyramidal-peaked, axially-symmetric puzzle elements of regular pyramidal form in an orientation with the apices of the pyramids touching and with an alignment that satisfies the condition that the visual indicia on each edge of the visible, apex-opposed, polygonal base face of each puzzle element conforms to the visual indicia on the visible base face edges of all adjacent puzzle elements. One solid polyhedron of the preferred embodiment is the twelve-sided dodecahedron, a front view of which is shown in FIG. 1 with the shading pattern indicia shown to be matching across each edge. Figure 2 shows several views of the same dodecahedron again with matching pattern indicia and with the twelve sides (faces) numbered in a clockwise manner from the top down for reference. Figure 2a shows the front view with face 1 on top. Figure 2b is the back view while Figure 2c is the top view and Figure 2d is the bottom view. Face 2 is shown on the left in Figure 2a and proceeding clockwise around the back of the dodecahedron are shown faces 3 and 4 in Figure 2b with faces 5, 6 and 7 shown in Figure 2a; faces 8, 9 and 10 shown in Figure 2b; face 11 shown in Figure 2a; and face 12 shown in Figure 2d. The clockwise orientation of the numbering scheme is shown from the top in Figure 2c and the counter-clockwise numbering when looking up from the bottom (making the sequence opposite in direction from the top-down scheme) is shown in Figure 2d.

In the preferred embodiment yielding a dodecahedron, the base face of each pyramidal puzzle element 10 is a regular pentagon 11 as shown in Figure 3a and the resulting 5-pyramid is an axially-symmetric right pyramid where a line of height h 14 joining the centroid of the pentagonal base face 12 and the apex of each pyramid 13 is perpendicular to that base face as shown in Figure 3b. Using a set of twelve appropriately-proportioned 5-pyramidal puzzle elements expressing specifically-chosen indicia, the completed dodecahedron shown in Figure 1 can be constructed with matching visual indicia on each side of the thirty exposed visible edges of the dodecahedron. For a dodecahedron of the preferred embodiment, the appropriate proportions for the 5-pyramidal puzzle elements is that the height h 14 of the puzzle element is a factor of 1.113516 times the length of a side s 15 of the pentagonal base face.

The visual indicia of the invention can consist of alphanumeric values, color elements, abstract patterns or geometric designs. In a preferred embodiment, each base face edge of each 5-pyramidal puzzle element exhibits one of five distinct color/pattern elements as shown, for example, in FIG. 4 using the shading pattern indicia shown on the central base face of FIG. 1 (also labeled as face 6 in FIG. 2a). The shading pattern indicia is shown with an inset alphabetic character (in caps) for reference to denote each particular and distinctive shading pattern as follows: dark shading A 16, crosshatch shading B 17, white dots on dark shading C 18, black dots on light shading D 19 and light shading E 20. This represents one sequence of five distinct shading pattern indicia. Each of the twelve 5-pyramidal puzzle elements in FIG.1 and FIG. 2 presents a distinct sequence of shading pattern indicia combinations in a clockwise direction when viewing the base face directly.

The puzzle elements are assembled by placing the puzzle elements in an orientation with the apices of each pyramid touching and with an alignment such that the visual indicia on the edges of the pentagonal base face of each puzzle element conform to the visual indicia on the base face edges of all adjacent puzzle elements as shown in FIG. 1 and FIG. 2. The conformance requirement for the preferred embodiment is that the indicia on adjacent edges match each other but other conformance requirements – such as having numbered indicia additively total a specific value – are possible. The conformance requirement that the edges must satisfy can be visually verified by the puzzle solver.

FIG. 5 shows a flat view of the arrangement of the twelve pentagonal faces of a dodecahedron of the preferred embodiment. The edges of each numbered face are labeled with alphabetic characters from **a** through **e** for reference use in the analytical solution and evaluation processes. The alphabetic numbering proceeds in a clockwise manner around the face with the **a**-labeled edge adjacent to the lowest numbered face surrounding that face. So, for example, the **a** edge of face 1 is adjacent to face 2 and the **a** edge of face 2 is adjacent to face 1. Similarly, the **a** edge of face 7 is adjacent to face 2 and the **a** edge of face 12 is adjacent to face 7. If – as in the preferred embodiment – each face exhibits a unique sequence of indicia, then a solution to the puzzle will have the characteristic that adjacent faces exhibit identical indicia. For example, edge **1a** and edge **2a** will exhibit the same indicia as will **1b** and **3a**, **2c** and **7a**, **7d** and **12a**, etc., until all thirty edge pairs are identically matched. The property of matching edge-pairs is used in determining solutions to the puzzle and in evaluating the difficulty in finding any given solution.

This invention discloses an analytical process to determine combinations of indicia on the puzzle elements resulting in viable, non-trivial, challenging solutions to the assembly of the pre-determined solid geometric shape. Some potential configurations of indicia can yield multiple solutions while other potential configurations can yield no solutions whatsoever. For example, if the chosen indicia for the puzzle elements were coloration and if every edge of every puzzle element were to contain the same indicium – blue, for instance – then any puzzle element could be placed adjacent to any other puzzle element in any rotational alignment, making the solution of the puzzle extremely trivial. Conversely, if the chosen indicia for the puzzle elements were numbers and if every edge of every puzzle element were to contain a distinct number, then no puzzle element could ever be placed adjacent to another, making no solution possible whatsoever.

For the preferred embodiment of 5-pyramidal puzzle elements completing the dodecahedron, five distinct indicia are chosen – one for each of the five edges of each puzzle element. Without repeating any indicium on any puzzle element and eliminating rotationally-identical alternatives, there are twenty-four possible combination of five distinct indicia represented alphabetically as follows: ABCDE, ABCED, ABDCE, ABDEC, ABECD, ABEDC, ACBDE, ACBED, ACDBE, ACDEB, ACEBD, ACEDB, ADBCE, ADBEC, ADCBE, ADCEB, ADEBC, ADECB, AEBCD, AEBDC, AECBD, AECDB, AEDBC, AEDCB. From these twenty-four possible combinations of indicia, twelve must be selected that provide a viable solution to the puzzle.

An example of a set of twelve combinations of indicia that yield a solution to the puzzle of the preferred embodiment is as follows: ABCDE, ABCED, ABDCE, ABDEC, ABECD, ABEDC, ACBDE, ACBED, ACDBE, ACEBD, ADCBE, and AECBD. These indicia combinations complete a conforming dodecahedron in the following arrangement as shown in FIG. 6: ABCDE, ACDBE, ABECD, ABDEC, ACBDE, ACEBD, ABCED, ACBED, AECBD, ADCBE, ABDCE, and ABEDC.

Another example of a set of twelve combinations of indicia that yield a solution to the puzzle of the preferred embodiment is as follows: ABCDE, ABDEC, ABECD, ACBDE, ACDEB, ACEBD, ADEBC, ADECB, AEBCD, AEBDC, AECBD, and AECDB. These indicia complete a conforming dodecahedron in the following sequence as shown in FIG. 7: ABCDE, ADEBC, AEBCD, ACEBD, ABECD, ABDEC, AEBDC, AECDB, ACDEB, ACBDE, AECBD, and ADECB.

This set of combinations of indicia has an alternative conforming arrangement using eight combinations of indicia as shown in FIG. 8: ABCDE, ABDEC, ADEBC, ACEBD, AEBCD, ABECD, AECBD and AEBDC. However, the four remaining combinations – ACBDE, AECDB, ACDEB and ADECB – cannot complete the remainder of this puzzle. Specifically, the combination of indicia necessary for face 9 requires the partial clockwise sequence BDC. None of the remaining combinations contains that partial sequence. Similarly, the combination of indicia necessary for face 10 requires the partial clockwise sequence ED. None of the remaining elements contains that partial sequence either. Combinations necessary for faces 11 and 12 require the partial clockwise sequences EDB and DC, respectively. Again, none of the remaining elements contains those partial sequences. Thus, FIG. 8 shows an arrangement of eight of the available combination of indicia that partially completes the puzzle but further progress in completing the puzzle with the remaining indicia combinations is not possible.

The flat view of the dodecahedron shown in FIG. 5 demonstrates which edges of each face are adjacent to those of other faces. The edge relationships of FIG. 5 can be completely represented in a table as shown in FIG. 9. For each face listed on the column at the left, the edges (indicated as the face number followed by the edge letter in lower case) that are adjacent to the faces shown across the top are shown in the corresponding cells of the table. For example, edge **1a** of face 1 is adjacent to face 2. Similarly, edge **1b** is adjacent to face 3 and edge **2e** of face 2 is adjacent to face 3. The table has the added advantage that reading down a column labeled across the top gives the edges that are adjacent to that face. For example, the column labeled 1 shows that edges **2a**, **3a**, **4a**, **5a** and **6a** are adjacent to face 1. The process embodied in this table discloses a method for find combinations of indicia that provide a solution to the puzzle of the preferred embodiment.

The example solution of FIG. 6 is shown in the table in FIG. 10. The edge indicators in lower case letters are shown in the upper left of each cell while the representation of the indicia are shown in upper case letters in the lower right of each cell. Thus, the indicia for face 1 of FIG. 6 (ABCDE) are shown across the first row of the table in FIG. 10. To satisfy the matching constraint of the preferred embodiment, the edges adjacent to face 1 (reading down the first column) must have the same sequence of indicia (ABCDE) as the first row. Reading across the second row (face 2), the **a** edge must exhibit the indicium A (adjacent to face 1). Looking across the row, edge **e** of face 2 (adjacent to face 3) cannot exhibit the indicium B since the indicium for the preferred embodiment are not repeated on any given face. Similarly, edge **b** cannot exhibit indicium E. Twenty-three possible combinations of indicia remain after eliminating the combination used for face 1. Of those twenty-three, only thirteen satisfy the constraints on face 2; the combination ACDBE (reading clockwise around the face, i.e., in **abcde** order) chosen for face 2 in the example of FIG. 6 is one of those thirteen. That same sequence for the edges adjacent to face 2 is placed in the second column. For the third row, face 3 must exhibit B and E indicia on edges **a** and **b**, respectively, and edge **e** (adjacent to face 4) cannot exhibit indicia C (since face 4 already exhibits C on the edge adjacent to face 1). Thus, only four possible combinations remain as possibilities for face three – BEACD, BEDCA, BECAD and BECDA (or their rotation equivalents of ACDBE, ABEDC, ADBEC and ABECD). The combination of indicia chosen for face 3 in the example of FIG. 6 is one of those four (ABEDC). Similarly restrictions of the choices of the combinations of indicia for the remaining faces can be obtained from the table in FIG. 10 until a set of choices is found that satisfies all the constraining conditions applicable to a particular puzzle. In this example of the preferred embodiment, the chosen conditions are that no specific combination is exhibited on more than one face, each face exhibits each of the five capital-letter-identified indicia only once, and all thirty edges exhibit the same indicia on each of the adjacent faces.

There are a very large number of possible arrangements of distinct combinations of indicia. For the twelve faces of the dodecahedron with five non-repeating indicia on each face, there are over two million arrangements of twelve distinct indicia combinations. While manually finding the solution to indicia configuration choices is possible using the process described and exhibited in

FIG. 10, the manual process is a difficult task. However, the solution process of this invention can be implemented by computerized techniques to effectively and rapidly determine arrangements of indicia on any given set of puzzle elements that yield viable solutions. From all the arrangements of twelve combinations of five distinct indicia of the preferred embodiment, only three hundred and seventy-two sets (out of over two million possibilities) yield viable solutions to the puzzle. Fifty-two of those have multiple distinct arrangements of puzzle elements that solve the puzzle, so only three-hundred and twenty offer a single arrangement of puzzle elements as a solution where successful placement of each puzzle element is interdependent on the correct placement of every other puzzle element.

In solving the puzzle of the preferred embodiment and other puzzle configurations disclosed in this invention, the most challenging ones are those that offer the largest number of apparently viable partial solutions using some – but not all – of the puzzle elements. Another example of a complete solution was shown in FIG 7. The solution table for that example is shown in FIG. 11. However, even starting with the same combination of indicia for the first face (ABCDE), the arrangement shown in FIG. 8 demonstrates a partial solution to the puzzle using eight puzzle elements that cannot be completed with the remaining puzzle elements. The partial solution table for the example of FIG. 8 is shown in FIG. 12, which facilitates the examination of the remaining puzzle elements and rejects their success in completing the puzzle. For every set of twelve combinations of indicia that provide a distinct solution to the puzzle, a number of arrangements of those combinations yield only partial solutions to the puzzle. Completion of a table as shown in FIG. 12 for all possible arrangements of the combinations of indicia allows a determination the number of faces that can be matched with the available combinations of indicia (such as the eight faces that were successfully arranged in the example of FIG. 12) before an impasse is reached. Across all sets of indicia combinations, the greater the average number of faces that can be arranged before an impasse is reached the more difficult the puzzle comprised of that set of indicia is to complete.

The evaluation process of this invention examines each set of combinations of indicia that have been determined to provide a single solution to the puzzle. One indicia combination of the set is chosen as the starting point and all possible sequence arrangements of the remaining combinations are evaluated to determine the average number of faces that can successfully matched before an impasse is reached. Those sets of combinations of indicia with lower average numbers are concluded to provide puzzles with easier solutions while those with higher average numbers are concluded to provide puzzles that are more difficult to solve. Because exhaustive examinations of multiple alternatives are tedious and time-consuming to perform by hand, the evaluation process of this invention can be implemented most efficiently by computerized means.

Ideally, the constructed polyhedra of this invention do not utilize a supporting structure or framework. Therefore, the puzzle elements of the current invention beneficially employ magnetic, mechanical or electro-mechanical processes to secure matching puzzle elements. In the preferred embodiment, the 5-pyramidal puzzle elements contain transversely-polarized magnetic attachment units on or inside each radial face placed to secure two correctly aligned radial faces when they are placed together. In the absence of the protuberances and cavities described below, each radial face of any 5-pyramidal puzzle element could be magnetically secured to any radial face of any other 5-pyramidal puzzle element. This is in stark contrast to every other known puzzle design using magnetic mechanisms to secure three-dimensional puzzle elements since every other design uses either singly polarized magnetic elements or "flippable" double polarized magnetic elements such that some aligned puzzle elements are attracted to only certain other puzzle elements and will not attract and secure any and all other puzzle elements. In the preferred embodiment, the transversely-polarized magnetic attachment units can be applied in conjunction with the arrangement of protuberances and cavities to assure that only correctly matched puzzle elements are securely interjoined in completing the polyhedron.

The placement of the transversely-polarized magnetic attachment units 21 on a 5-pyramidal puzzle element 10 in the preferred embodiment is shown in FIG. 13. The top view looking down onto the puzzle element from above the apex is shown in FIG. 13a while the side view is shown in FIG. 13b. Note that the arrangement of the polarization (shown as N for north and S for south) is identical for each radial face of the puzzle element. Were another puzzle element to be placed adjacent to the one shown with the radial faces aligned (base face edges touching and apices together), the N from one would attract and attach with the S from the other while the S would attract and attach with the N. Such would be the case for any and all aligned puzzle elements as shown in a flat view in FIG. 14. Through this attachment, the completed dodecahedron could be assembled.

Because of the three-dimensional nature of the completed polyhedron, it may be difficult for all the constraints to be simultaneously observed and verified visually. Accordingly, in the preferred embodiment, the puzzle elements can exhibit physical characteristics to assure that only matching puzzle elements may be aligned and interjoined. These physical characteristics take the form of an arrangement of protuberances and cavities on the radial faces of the 5-pyramidal puzzle elements such that the protuberances will securely fit into matching cavities and such that the arrangement of protuberances and cavities on each radial face correspond to the visual indicium on the base face edge shared by that radial face. Each cavity serves as a snugly fitting receptacle for a protuberance. Thus, only the radial faces of 5-pyramidal puzzle elements with matching base face edges may be successfully interjoined. Radial faces with non-matching base face edge indicia may have an arrangement of protuberances and cavities that prevent interjoining.

FIG. 15 provides a detailed look at a set of protuberances and cavities on a radial face of a puzzle element. A view from above the radial face is shown in FIG. 15a with the widely-spaced protuberance 22 shown on the left of the radial face and the corresponding cavity 23 on the right. The same widely-spaced protuberance and cavity set is shown from the base face end of the radial face in FIG. 15b and from the side of the radial face in FIG. 15c. A matching pair of widely-spaced protuberance and cavity sets is shown in FIG. 15d where it is clear that the protuberance on the upper radial face will fit into the cavity on the lower face and the protuberance on the lower radial face will fit into the cavity on the upper one. A side view of that same pair is shown in FIG. 15e. A centrally-spaced pair of protuberance and cavity sets is shown in FIG. 15f while a narrowly-spaced pair is shown in FIG. 15g.

Three radial faces of a 5-pyramidal puzzle element 10 with transversely-polarized magnetic attachment units 21 and protuberance and cavity sets 24 on each face are shown in FIG. 16.

Other polyhedra in addition to the dodecahedron may be used as the puzzle objective of this invention. For example, another Platonic solid – the icosahedron – may be constructed from twenty 3-pyramidal puzzle elements 25 of the type shown in FIG. 17 where the height of the pyramid h 26 is equal to .755761 times the length s 27 of an edge of the triangular base face. It should be noted that while each 3-pyramid puzzle element has four triangular faces, the 3-pyramid puzzle element used to construct an icosahedron is not a regular tetrahedron with all sides equal since the radial edges of that 3-pyramid puzzle element are about 5% shorter than the edges of the triangular base face. FIG. 18 shows a flat view of an icosahedron using 3-pyramidal puzzle elements with the numbered faces showing lower case alphabetic-labeled edges. The 3-pyramidal puzzle element can also be used to construct the octahedron, another Platonic solid. The arrangement shown in FIG. 18 for the icosahedron corresponds to that of FIG. 5 for the dodecahedron and allows for the solution and evaluation processes of this invention to be used in a similar manner to discover solutions for and to evaluate the difficulty of an icosahedron-type puzzle.

While some polyhedra such as the dodecahedron and the icosahedron use identical puzzle elements, several polyhedra may be constructed from a combination of appropriately-proportioned pyramidal puzzle elements with 3, 4, 5, 6, 8 or 10 base face edges. A pyramidal puzzle element of four base sides 28 – a 4-pyramid – is shown in FIG. 19 where the ratio of the height of the pyramid h 29 is a factor of the length s 30 of an edge of the square base face specified for the characteristics of the polyhedron for which that puzzle element will be used. Similarly, FIG. 20 shows 6-pyramidal puzzle element 31, FIG. 21 shows an 8-pyramidal puzzle element 32 and FIG. 22 shows a 10-pyramidal puzzle element 33. The characteristic ratio relating the height and edge length of these pyramidal puzzle elements is specific to the completed polyhedron that will be constructed with those puzzle elements.

The current invention includes geometric logic puzzles characterized by independent, solid, three-dimensional dipyramidal puzzle elements with visible indicia on each identically-shaped triangular face of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. One such polyhedron – the stellated dodecahedron – is shown in FIG. 23.

Each apex-opposed triangular face of each dipyramidal puzzle element expresses a visible design indicium that can be alphanumeric values, color elements, abstract patterns or geometric designs. Dipyramidal puzzle elements consisting of only triangular faces are distinguished from pyramidal puzzle elements by possessing two distinct apex points instead of just one and no base face. A dipyramidal puzzle element 34 with five central edges – a 5-dipyramid – is shown in FIG. 24 for construction of a stellated dodecahedron. The characteristic ratio of the height h 35 from the center of the puzzle element to either apex relative to the edge length s 36, as shown in detail in FIG. 24a, is identical to the characteristic ratio of 1.113516 from the 5-pyramid used to construct a regular dodecahedron. The edges along the center of the dipyramidal puzzle element 34 and the associated apex-opposed faces are labeled with lower case alphabetic characters from **a** through **e** and from **f** through **j** to designated visual indicia as shown in FIG. 24b for reference use in the analytical solution and evaluation processes. The alphabetic numbering proceeds in a clockwise manner around the puzzle element when looking down from above the exposed apex with the opposed apex placed in the center of the completed polyhedron. Were the puzzle element to be flipped, i.e., rotated such that the positions of the apices were traded, then the edges **f** through **j** would be used in place of the **a** through **e** exposed edges in the analytical solution and evaluation processes.

As is shown in FIG. 24, a dipyramidal puzzle element 34 may be oriented in two distinct directions wherein 1) one set of triangular faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other, apex-opposed, triangular faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously exposed and visible faces are instead placed at the center of the complete polyhedron and the previously interior triangular faces are visibly exposed as apex-opposed faces on the exterior of the completed polyhedron.

Each dipyramidal puzzle element 34 may beneficially contain transversely-polarized magnetic attachment units 37 on or inside each triangular face as shown in FIG. 25. As with the pyramidal puzzle elements, each triangular face of a dipyramidal puzzle element 34 can exhibit physical characteristics corresponding with the indicium on its co-edged triangular face. A co-edged triangular face is that face of a dipyramidal puzzle element 34 with which the initial triangular face shares a central edge and which face is connected to the opposing apex. A central edge is an edge of the three-dimensional dipyramidal puzzle element 34 that does not contact either apex. An example of the physical characteristics of each triangular face that can be exhibited as patterns of protuberances and cavities 38 is shown in FIG. 26. The protuberances and cavities are aligned such that the face of a dipyramidal puzzle element 34 interjoins with the triangular face of another dipyramidal puzzle element when matching co-edged triangular faces of the two dipyramidal puzzle elements are placed together at their central edge. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two dipyramidal puzzle elements with non-matching co-edged triangular faces together. A dipyramidal puzzle element 34 with both the transversely-polarized magnetic attachment units 37 and several patterns of protuberances and cavities 38 on the triangular faces is shown in FIG. 27.

Three-dimensional polyhedra with matching indicia on both sides of each exposed central edge results when all dipyramidal puzzle elements with matching triangular faces are aligned and interjoined. The completed polyhedra from dipyramidal puzzle elements are referred to in this invention as stellated, or star-like, forms although they are not necessarily the result of geometric stellation since the dipyramidal puzzle elements need not strictly exhibit the extension of internal faces or edges of the polyhedra.

The solution and evaluation processes of this invention are used in the same manner to discover solutions for and evaluate the difficulty of a stellated dodecahedron puzzle constructed from dipyramidal puzzle elements in exactly the same manner as they were used for the standard dodecahedron of the preferred embodiment.

Other stellated polyhedra such as the stellated icosahedron may be created from 3-dipyramidal puzzle elements 39 shown in FIG. 28 where the characteristic ratio of the height h 40 from the center of the puzzle element to either apex relative to the edge length s 41, as shown in detail in FIG. 28a, is identical to the characteristic ratio of .755761 from the 3-pyramid used to construct a regular icosahedron. The edges of each end of the dipyramidal puzzle element are labeled with lower case alphabetic characters from **a** through **c** and from **d** through **f** as shown in FIG. 28b for reference use in the analytical solution and evaluation processes. The alphabetic numbering proceeds in a clockwise manner around the puzzle element when looking down from above the apex of each end. The 3-dipyramidal puzzle element can also be used to construct the stellated octahedron, another Platonic solid.

Other dipyramidal puzzle elements such as the 4-dipyramidal puzzle element (shown in FIG. 29), the 6-dipyramidal puzzle element (shown in FIG. 30), the 8-dipyramidal puzzle element (shown in FIG. 31) and the 10-dipyramidal puzzle element (shown in FIG. 32) can be used to construct other stellated polyhedra. Those polyhedra include stellated versions of the Archimedean solids and other uniform and non-uniform polyhedra.

The current invention also includes geometric logic puzzles characterized by independent, solid, three-dimensional trapezohedral puzzle elements with visible indicia on each identically-shaped deltoid face of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. One such polyhedron – an alternately-stellated dodecahedron – is shown in FIG. 33.

Each half of each apex-opposed deltoid face of each trapezohedral puzzle element expresses visible design indicium that can be alphanumeric values, color elements, abstract patterns or geometric designs. Trapezohedral puzzle elements consisting of only deltoid faces are distinguished from pyramidal puzzle elements and are similar to dipyramidal puzzle elements by possessing two distinct apex points instead of just one and no base face. A trapezohedral puzzle element 42 with ten central edges – a 5-trapezohedron – is shown in FIG. 34 for construction of an alternately-stellated dodecahedron. The characteristic height h from the center of the puzzle element to either apex is identical to that of the 5-dipyramidal puzzle element used to construct a stellated dodecahedron. The edges along the center of the trapezohedral puzzle element and associated apex-opposed faces are labeled with lower case alphabetic characters from **a** through **j** and from **k** through **t** to designate visual indicia as shown in FIG. 34b for reference use in the analytical solution and evaluation processes. The alphabetic numbering proceeds in a clockwise manner around the puzzle element when looking down from above the exposed apex with the opposed apex placed in the center of the completed polyhedron. Were the puzzle element to be flipped, i.e., rotated such that the positions of the apices were traded, then the edges **k** through **t** would be used in place of the **a** through **j** edges in the analytical solution and evaluation processes.

As is shown in FIG. 34, a trapezohedral puzzle element 42 may be oriented in two distinct directions wherein 1) one set of deltoid faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other, apex-opposed, deltoid faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously exposed and visible faces are instead placed at the center of the complete polyhedron and the previously interior deltoid faces are visibly exposed as apex-opposed faces on the exterior of the completed polyhedron.

Using indicia labeling for each half of each deltoid face, a flat view of an , alternately-stellated dodecahedron with the numbered apices showing lower case alphabetic-labeled edges is shown in FIG. 35. The angles of the deltoid faces have been diminished for simplicity of presentation in the flat view. As before, the solution and evaluation processes of this invention can be used in the same manner to discover solutions for and to evaluate the difficulty of a puzzle constructed from trapezohedral puzzle elements.

Each trapezohedral puzzle element 42 may beneficially contain transversely-polarized magnetic attachment units on or inside each deltoid face as shown in FIG. 36. As with the dipyramidal puzzle elements, each deltoid face of a trapezohedral puzzle element 42 can exhibit physical characteristics corresponding with the indicium on its co-edged deltoid face. A co-edged deltoid face is that face of the trapezohedral puzzle element 42 with which the initial deltoid face shares a central edge and which face is connected to the opposing apex. A central edge is an edge of the three-dimensional trapezohedral puzzle element 42 that does not contact either apex. An example of the physical characteristics of each deltoid face of a trapezohedral puzzle element 42 that can be exhibited as patterns of protuberances and cavities is shown in FIG. 37. The protuberances and cavities are aligned such that the deltoid face of a trapezohedral puzzle element 42 interjoins with the deltoid face of another trapezohedral puzzle element when matching co-edged deltoid faces of the two puzzle elements are placed together at their central edge. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two puzzle elements with non-matching co-edged deltoid faces together. A trapezohedral puzzle element 42 with both the transversely-polarized magnetic attachment units and several patterns of protuberances and cavities on the deltoid faces is shown in FIG. 38.

Three-dimensional polyhedra with matching indicia on both sides of each exposed central edge result when all trapezohedral puzzle elements with matching deltoid faces are aligned and interjoined. The completed polyhedra from trapezohedral puzzle elements are referred to in this invention as alternately-stellated forms.

The solution and evaluation processes of this invention may be used in the same manner to discover solutions for and to evaluate the difficulty of an alternately-stellated dodecahedron puzzle constructed from trapezohedral puzzle elements in exactly the same manner as they were used for the standard dodecahedron of the preferred embodiment.

Other alternately-stellated polyhedra may be created from 3-trapezohedral, 4-trapezohedral, 6-trapezohedral, 8-trapezohedral and 10-trapezohedral puzzle elements in a manner similar to those stellated polyhedra constructed from dipyramidal puzzle elements.

The current invention also includes geometric logic puzzles characterized by independent, solid, three-dimensional rhombohedric puzzle elements with visible indicia on all identically-shaped parallelogram faces of each puzzle element that are assembled to create a three-dimensional solid polyhedron while satisfying specified constraining conditions. One such puzzle constructs the rhombic hexecontahedron shown in FIG. 39.

Each apex-opposed parallelogram face of each rhombohedric puzzle element expresses visible design indicium that can be alphanumeric values, color elements, abstract patterns or geometric designs. Rhombohedric puzzle elements are distinguished from pyramidal, dipyramidal and trapezohedral puzzle elements by possessing only parallelogram faces but like dipyramidal and trapezohedral puzzle elements they possess two distinct apex points and no base face. A rhombohedric puzzle element 43 is shown in FIG. 40 where the horizontal side view is shown in FIG. 40a, a top view looking down from above one apex is shown in FIG. 40b and a linked vertical side view is shown in FIG. 40c. The characteristic ratio relating the long diagonal length i and edge length of these rhombohedric puzzle elements is specific to the completed polyhedron that will be constructed with those puzzle elements. Each parallelogram face requires two indicia since there are two distinct edges that are shared with adjacent puzzle elements in the completed polyhedron. An example of the positioning of pairs of indicia on the parallelogram faces of a rhombohedric puzzle element 43 is shown in detail in FIG. 41. The lower case alphabetic labeling of the edges of a rhombohedric puzzle element 43 is shown in FIG. 42. Note that from above, the rhombohedric puzzle element appears to be similar to a triangular face with a split pair of edge labels, one on each side of each exterior edge. The angles of the parallelogram faces have been diminished for simplicity of presentation. The indicia labeling of **a** through **f** shown in FIG. 42a represent those indicia visible when looking down on that exposed apex with the opposed apex placed in the center of the completed polyhedron. Were the puzzle element 43 to be flipped, the indicia labeling of **g** through **l** would instead be visible and those indicia would be used in the place of the exposed **a** through **f** for the solution and evaluation processes. Using indicia labeling for each half of each parallelogram face, a flat view of a rhombic hexecontahedron that is similar to the view of an icosahedron with the numbered faces showing lower case alphabetic-labeled split edges is shown in FIG. 43. Accordingly, the solution and evaluation processes of this invention can be used in the same manner to discover solutions for and to evaluate the difficulty of a puzzle constructed from rhombohedric puzzle elements.

Similar to dipyramidal and trapezohedral puzzle elements, rhombohedric puzzle elements may be oriented in two distinct directions wherein 1) one set of parallelogram faces share vertex points at the apices of the puzzle elements with the center of the complete polyhedron and the other parallelogram faces are visibly exposed or 2) the apices of the puzzle elements shared by the previously visibly exposed faces are instead placed at the center of the complete polyhedron and the previously interior parallelogram faces are visibly exposed on the exterior of the completed polyhedron.

The rhombohedric puzzle elements may beneficially contain transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside each parallelogram face aligned to secure two matching parallelogram faces when they are placed together. As with the pyramidal and dipyramidal puzzle elements, each parallelogram face of a rhombohedric puzzle element 43 can exhibit physical characteristics corresponding with the indicium on its two co-edged parallelogram faces as shown in FIG. 44. Co-edged parallelogram faces are those two faces of the rhombohedric puzzle element 43 with which the initial parallelogram face shares a central edge and which faces are connected to the opposing apex. A central edge is an edge of the three-dimensional rhombohedric puzzle element 43 that does not contact either apex. The physical characteristics of each parallelogram face consists of patterns of protuberances and cavities aligned such that the face of a rhombohedric puzzle element 43 interjoins with the parallelogram face of another puzzle element when matching co-edged parallelogram faces of the two puzzle elements are placed together along their central edges. The patterns of protuberances and cavities prevent interjoining when an attempt is made to place two rhombohedric puzzle elements with non-matching co-edged parallelogram faces together. A rhombohedric puzzle element 43 with both the transversely-polarized magnetic attachment units and several patterns of protuberances and cavities on the parallelogram faces is shown in FIG. 45.

The three-dimensional polyhedron with matching indicia on both sides of each exposed central edge is constructed and the puzzle completed when all rhombohedric puzzle elements with matching parallelogram faces are aligned and interjoined. One completed polyhedra that can be created from rhombohedric puzzle elements is the rhombic hexecontahedron shown in FIG 39.

The current invention describes the use of transversely-polarized magnetic, mechanical or electro-mechanical attachment units on or inside the attaching faces of each three-dimensional, pyramidal, dipyramidal, trapezohedral or rhombohedric puzzle element so that any puzzle element that is correctly aligned with an adjoining puzzle element is secured to complete the final polyhedra. The resulting polyhedron consists of a three-dimensional object that can be rotated, examined and handled without the constraint of a supporting base or structure. However, the attachment mechanism allows attaching faces of separate puzzle pieces to be disengaged manually, as is desirable when trying to align pieces that do not satisfy the constraining conditions or to disassemble the puzzle to allow the challenge of reassembling it at another time. While this specification has specifically described the use of magnetic mechanisms for the purpose of securing the puzzle elements, this description should not be construed as a limitation on the scope of the invention.

The current invention may use physical characteristics on the attaching faces of each pyramidal, dipyramidal, trapezohedral or rhombohedric puzzle element consisting of patterns of protuberances and cavities, each of which cavities serve as a snugly fitting receptacle for a protuberance, corresponding to the visual indicia of corresponding edges such that only properly aligned puzzle elements with matching visible indicia on the exposed faces may be successfully interjoined. Those patterns of protuberances and cavities also prevent interjoining when an attempt is made to place the properly aligned faces of two non-matching puzzle elements together. While this specification has specifically described a particular configuration for patterns of protuberances and cavities corresponding to the visual indicia of corresponding edges, this description should not be construed as a limitation on the scope of the invention.

Computerized processes can be created to represent puzzles of the types disclosed herein in visual form and allow for selection and placement of pyramidal, dipyramidal, trapezohedral or rhombohedric puzzle elements within that visual representation. These computerized manifestations and representations of three-dimensional polyhedra-type geometric logic puzzles allow for the puzzles to be solved through interaction with computerized representations of the puzzle elements. While this specification specifically describes a particular approach for physically solid, three-dimensional polyhedra-type geometric logic puzzles, those puzzles also can be solved through interaction with computerized representations of the puzzle elements. Thus, this description of the preferred embodiment should not be construed as a limitation on the scope of the invention.

In addition to the dodecahedron, the icosahedron, their stellated counterparts and the rhombic hexecontahedron described above, the current invention can also be implemented to make standard and stellated puzzles yielding other polyhedra (shown in flat views in the noted figures) including FIG. 46 the octahedron (from eight 3-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 47 the cuboctahedron (from eight 3-sided, axially-symmetric, pyramidal-peaked pyramid puzzle elements and six 4-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 48 the small rhombicuboctahedron (from eight 3-sided, axially-symmetric, pyramidal-peaked puzzle elements and eighteen 4-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 49 the icosidodecahedron (from twenty 3-sided, axially-symmetric, pyramidal-peaked puzzle elements and twelve 5-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 50 the rhombicosidodecahedron (from twenty 3-sided, axially-symmetric, pyramidal-peaked puzzle elements, thirty 4-sided, axially-symmetric, pyramidal-peaked puzzle elements and twelve 5-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 51 the truncated icosahedron (from twelve 5-sided, axially-symmetric, pyramidal-peaked puzzle elements and twenty 6-sided, axially-symmetric, pyramidal-peaked puzzle elements), FIG. 52 the great rhombicuboctahedron (from twleve 4-sided, axially-symmetric, pyramidal-peaked puzzle elements, eight 6-sided, axially-symmetric, pyramidal-peaked puzzle elements and six 8-sided, axially-symmetric, pyramidal-peaked puzzle elements) and FIG 53 the rhombitruncated icosidodecahedron (from thirty 4-sided, axially-symmetric, pyramidal-peaked puzzle elements, twenty 6-sided, axially-symmetric, pyramidal-peaked puzzle elements and twelve 10-sided, axially-symmetric, pyramidal-peaked puzzle elements).

Two other Platonic solids, the tetrahedron and the cube, could be used as the final polyhedra for the puzzle of this invention using four 3-sided, axially-symmetric, pyramidal-peaked puzzle elements and six 4-sided, axially-symmetric, pyramidal-peaked puzzle elements, respectively. Since the very small number of puzzle elements makes those two puzzles extremely simple, no figures or descriptions have been included. However, the design of these puzzle elements and choice of indicia for these two puzzles are essentially identical to the processes disclosed herein for other polyhedra and the absence of detailed descriptions should not be construed as limitations on the scope of the invention.

This invention includes the use of visual indicia on the pyramidal, dipyramidal, trapezohedral or rhombohedric puzzle elements. In some implementations, the visual indicia may be a compounded form of two or more types of indicia (such as abstract patterns placed in a background of color elements) with each type of indicia chosen in such a way as to represent a distinct puzzle as is shown in FIG. 54. Five distinct shading pattern indicia are shown on a five-edged puzzle element as 44, 45, 46, 47 and 48 while a combination of just three geometric design indicia are inset into the shading pattern of each edge. A square geometric design indicium is shown as 49 while triangular indicia are shown at 50 and 51 and octahedral indicia are shown at 52 and 53. The solution and evaluation processes of this invention can be to discover solutions for and evaluate the difficulty of puzzles using combinations of just three indicia (with some repetition of single indicia) in a similar manner to that previously described for five distinct indicia. Solutions to such puzzles are also possible with other numbers of distinct visual indicia and the absence of detailed descriptions of these possibilities should not be construed as limitations on the scope of the invention. A single set of such compound puzzle elements can be used to provide two or more distinctly different puzzle solving challenges with distinctly different levels of difficulty.

The axially-symmetric, pyramidal-peaked puzzle elements disclosed herein included pyramidal, dipyramidal, trapezohedral or rhombohedric forms. Alternative three-dimensional puzzle elements for puzzles as disclosed in this invention could be created from the joining of two or more of the axially-symmetric, pyramidal-peaked puzzle elements disclosed herein or from the dissection into two or more separate puzzle elements of the axially-symmetric, pyramidal-peaked puzzle elements disclosed herein. While this specification specifically describes several examples of axially-symmetric, pyramidal-peaked puzzle elements, these descriptions should not be construed as limitations on the scope of the invention.

Although the present invention has been described in terms of the presently preferred embodiment, it is to be understood that such disclosure is purely illustrative and is not to be interpreted as limiting. Consequently, without departing from the spirit and scope of the invention, various alterations, modifications, and/or alternative applications of the invention will, no doubt, be suggested to those skilled in the art after having read the preceding disclosure. Accordingly, it is intended that the following claims be interpreted as encompassing all alternations, modifications, or alternative applications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A puzzle, comprising:

a. a plurality of independent, three-dimensional, axially-symmetric, pyramidal puzzle elements,

b. each puzzle element having a regular polygonal base with a base face defined by a plurality of symmetric base edges and radial faces extending from each base edge to a pyramidal peak,

c. each base edge being marked with desired indicia,

d. at least one matching condition for matching indicia on adjoining base edges of adjoining puzzle elements,

e. wherein successful completion of the puzzle is achieved when said puzzle elements are placed in an adjoining manner so that each base edge of each puzzle element adjoins an adjoining base edge of an adjoining puzzle piece to construct a complete polyhedron and the indicia of each base edge of each puzzle element satisfies the matching condition with respect to the indicia on the adjoining base edge of the adjoining puzzle element.

2. A puzzle according to claim 1, further comprising:

f. attachment means for releaseably attaching each puzzle element to each adjoining puzzle element.

3. A puzzle according to claim 2, wherein said attachment means comprises transversely-polarized magnets attached to each radial face of each puzzle element so as to releaseably attach said radial face of said puzzle element to a correctly aligned radial face of each other puzzle element.

4. A puzzle according to claim 2, wherein said attachment means comprises transversely-polarized magnets attached under each radial face of each puzzle element so as to releaseably attach said radial face of said puzzle element to a correctly aligned radial face of each other puzzle element.

5. A puzzle according to claim 2, wherein said attachment means comprises a mechanical attachment mechanism.

6. A puzzle according to claim 2, wherein said attachment means comprises an electro-mechanical attachment mechanism.

7. A puzzle according to claim 1, wherein said indicia comprises an element from a set of selected visual patterns, wherein each element of said set appears on at least one base edge.

8. A puzzle according to claim 7, wherein each visual pattern comprises a particular color.

9. A puzzle according to claim 7, wherein each visual pattern comprises a particular alphanumeric character.

10. A puzzle according to claim 7, wherein each visual pattern appears on a base edge of at least two puzzle elements and said matching condition is to adjoin base edges marked with same visual patterns.

11. A puzzle according to claim 7, wherein each base edge is marked with a first element from a first set of selected visual patterns and a second element from a second set of selected visual patterns, and successful completion of the puzzle is achieved when said puzzle elements are placed in an adjoining manner so that each base edge of each puzzle element adjoins an adjoining base edge of an adjoining puzzle piece to construct a complete polyhedron and either:

i. the first element marked on each base edge of each puzzle element satisfies a first matching condition with respect to the first element marked on the adjoining base edge of the adjoining puzzle element or

ii. the second element marked of each base edge of each puzzle element satisfies a second matching condition with respect to the second element marked on the adjoining base edge of the adjoining puzzle element.

12. A puzzle according to claim 1, wherein a radial face of a puzzle element has at least one physical protuberance and one receptacle for a protuberance corresponding to a protuberance and a receptacle for a protuberance on an adjoining radial face of an adjoining puzzle element.

13. A puzzle according to claim 12, wherein said physical protuberance of said radial face of said puzzle element fits into said receptacle for a protuberance on an adjoining radial face of an adjoining puzzle element when said puzzle element and said adjoining puzzle element adjoin only when the matching condition is satisfied.

14. A puzzle, comprising:

a. a plurality of independent, three-dimensional, axially-symmetric, dipyramidal puzzle elements,

b. each puzzle element having a central bisecting plane of regular polygonal shape defined by a plurality of symmetric central edges and radial faces extending from each central edge in opposite directions to two pyramidal peaks,

c. each radial face being marked with desired indicia,

d. at least one matching condition for matching indicia on adjoining radial faces of adjoining puzzle elements,

e. wherein successful completion of the puzzle is achieved when said puzzle elements are placed in an adjoining manner so that each radial face of each puzzle element adjoins an adjoining radial face of an adjoining puzzle piece to construct a stellated polyhedron and the indicia of each radial face of each puzzle element satisfies the matching condition with respect to the indicia on the adjoining radial face of the adjoining puzzle element.

15. A puzzle according to claim 14, further comprising:

f. attachment means for releaseably attaching each puzzle element to each adjoining puzzle element.

16. A puzzle according to claim 15, wherein said attachment means comprises transversely-polarized magnets attached to each radial face of each puzzle element so as to releaseably attach

said radial face of said puzzle element to a correctly aligned radial face of each other puzzle element.

17. A puzzle according to claim 15, wherein said attachment means comprises transversely-polarized magnets attached under each radial face of each puzzle element so as to releaseably attach said radial face of said puzzle element to a correctly aligned radial face of each other puzzle element.

18. A puzzle according to claim 14, wherein said indicia comprises an element from a set of selected visual patterns, wherein each element of said set appears on at least one radial face.

19. A puzzle according to claim 18, wherein each visual pattern appears on a radial face of at least two puzzle elements and said matching condition is to adjoin radial faces marked with same visual patterns.

20. A puzzle according to claim 14, wherein a radial face of a puzzle element has at least one physical protuberance and one receptacle for a protuberance corresponding to a protuberance and a receptacle for a protuberance on an adjoining radial face of an adjoining puzzle element.

21. A puzzle according to claim 20, wherein said physical protuberance of said radial face of said puzzle element fits into said receptacle for a protuberance on an adjoining radial face of an adjoining puzzle element when said puzzle element and said adjoining puzzle element adjoin only when the matching condition is satisfied.

22. A puzzle, comprising:

a. a plurality of independent, three-dimensional, axially-symmetric, trapezohedral puzzle elements,

b. each puzzle element having a central bisecting plane of regular polygonal shape and deltoid faces each with two central edges, which deltoid faces extend from each central edge in opposite directions to two pyramidal peaks,

c. each central edge being marked with desired indicia,

d. at least one matching condition for matching indicia on adjoining central edges of adjoining puzzle elements,

e. wherein successful completion of the puzzle is achieved when said puzzle elements are placed in an adjoining manner so that each central edge of each puzzle element adjoins an adjoining central edge of an adjoining puzzle piece to construct an alternately-stellated polyhedron and the indicia of each central edge of each puzzle element satisfies the matching condition with respect to the indicia on the adjoining central edge of the adjoining puzzle element.

23. A puzzle, comprising:

a. a plurality of independent, three-dimensional, axially-symmetric, rhombohedric puzzle elements,

b. each puzzle element having a central bisecting plane of regular polygonal shape and parallelogram faces each with two central edges, which parallelogram faces extend from each central edge in opposite directions to two pyramidal peaks,

c. each central edge being marked with desired indicia,

d. at least one matching condition for matching indicia on adjoining central edges of adjoining puzzle elements,

e. wherein successful completion of the puzzle is achieved when said puzzle elements are placed in an adjoining manner so that each central edge of each puzzle element adjoins an adjoining central edge of an adjoining puzzle piece to construct a stellated polyhedron and the indicia of each central edge of each puzzle element satisfies the matching condition with respect to the indicia on the adjoining central edge of the adjoining puzzle element.

24. A process for evaluating indicia to be exhibited on three-dimensional puzzle elements to enable selection of indicia that will allow puzzle elements to be assembled in a manner that satisfies a matching condition for such indicia, comprising the steps of:

a. assign a separate identifying moniker to each face of each puzzle element,

b. select an initial puzzle piece,

c. list, in adjacent order, the monikers assigned to each face of said initial puzzle piece,

d. select a second puzzle element,

e. determine whether said second puzzle element can be placed adjacent to said initial puzzle piece in a manner which satisfies said matching condition,

f. list, in adjacent order, the monikers assigned to each face of said second puzzle piece in any manner which, when adjacent to said initial puzzle piece, satisfies said matching condition,

g. repeat steps d – f for each remaining puzzle piece,

h. list and count all possible arrangements of puzzle elements in a manner that satisfies said matching condition,

j. analyze whether any of the possible arrangements of puzzle elements satisfies said matching condition.

25. A process for evaluating indicia to be exhibited on three-dimensional puzzle elements to enable selection of indicia that will allow puzzle elements to be assembled in a manner that satisfies a matching condition for such indicia with a desired degree of difficulty, comprising the steps of:

a. assign a separate identifying moniker to each face of each puzzle element,

b. select an initial puzzle piece,

c. list, in adjacent order, the monikers assigned to each face of said initial puzzle piece,

d. select a second puzzle element,

e. determine whether said second puzzle element can be placed adjacent to said initial puzzle piece in a manner which satisfies said matching condition,

f. list, in adjacent order, the monikers assigned to each face of said second puzzle piece in any manner which, when adjacent to said initial puzzle piece, satisfies said matching condition,

g. repeat steps d – f for each remaining puzzle piece,

h. list and count all possible arrangements of puzzle elements,

i. list and count all possible arrangements of puzzle elements in a manner that satisfies said matching condition,

j. analyze whether the ratio of possible arrangements of puzzle elements in a manner that satisfies said matching condition to the possible arrangement of puzzle elements indicates said desired degree of difficulty.

26. A computerized process representing three dimensional puzzle elements in visual form allowing for selection and placement of the puzzle elements within a visual representation for completion of a specified puzzle.

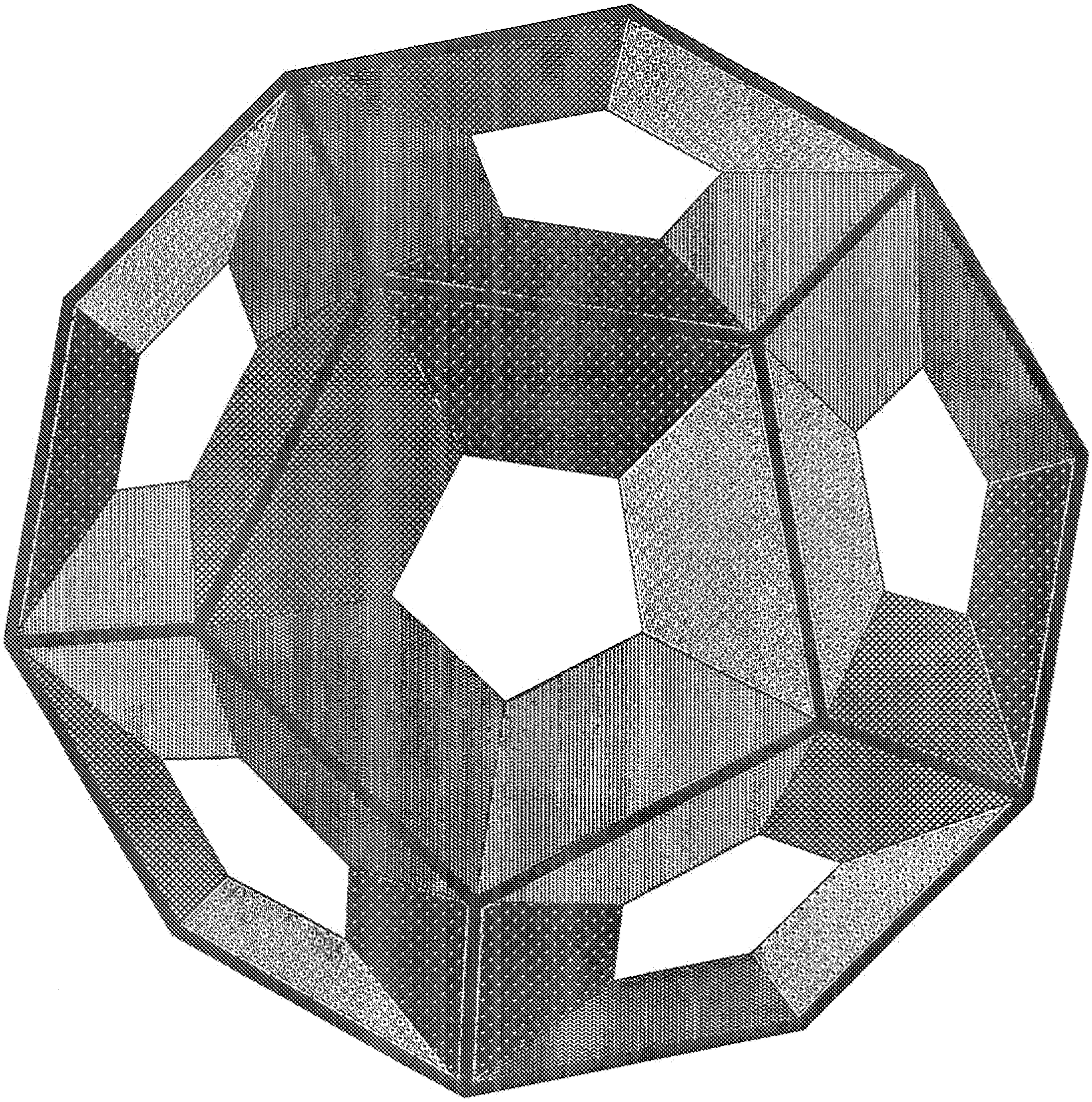

Figure 1

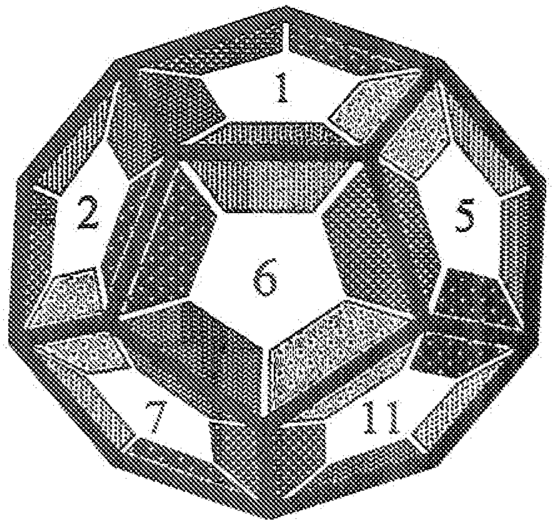

Figure 2a

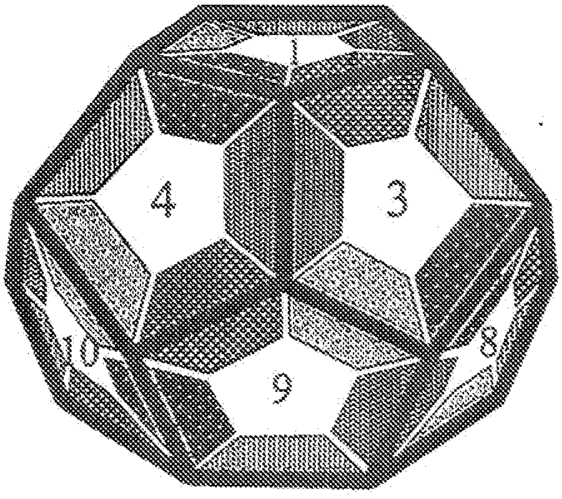

Figure 2b

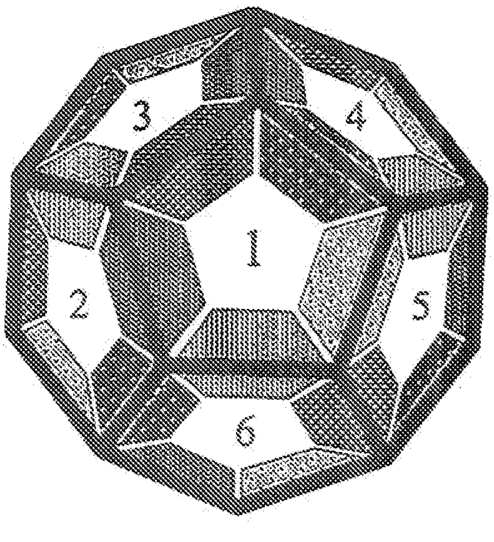

Figure 2c

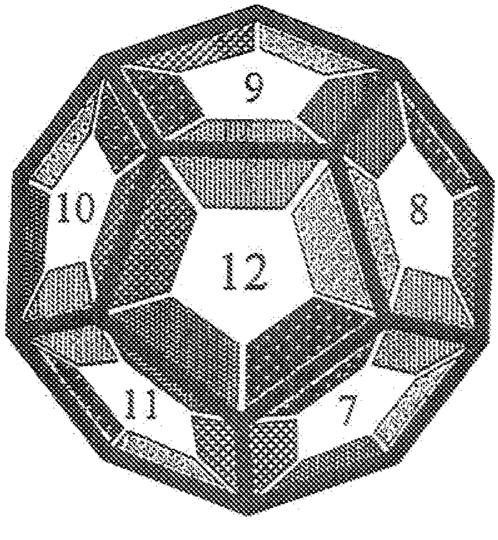

Figure 2d

Figure 2

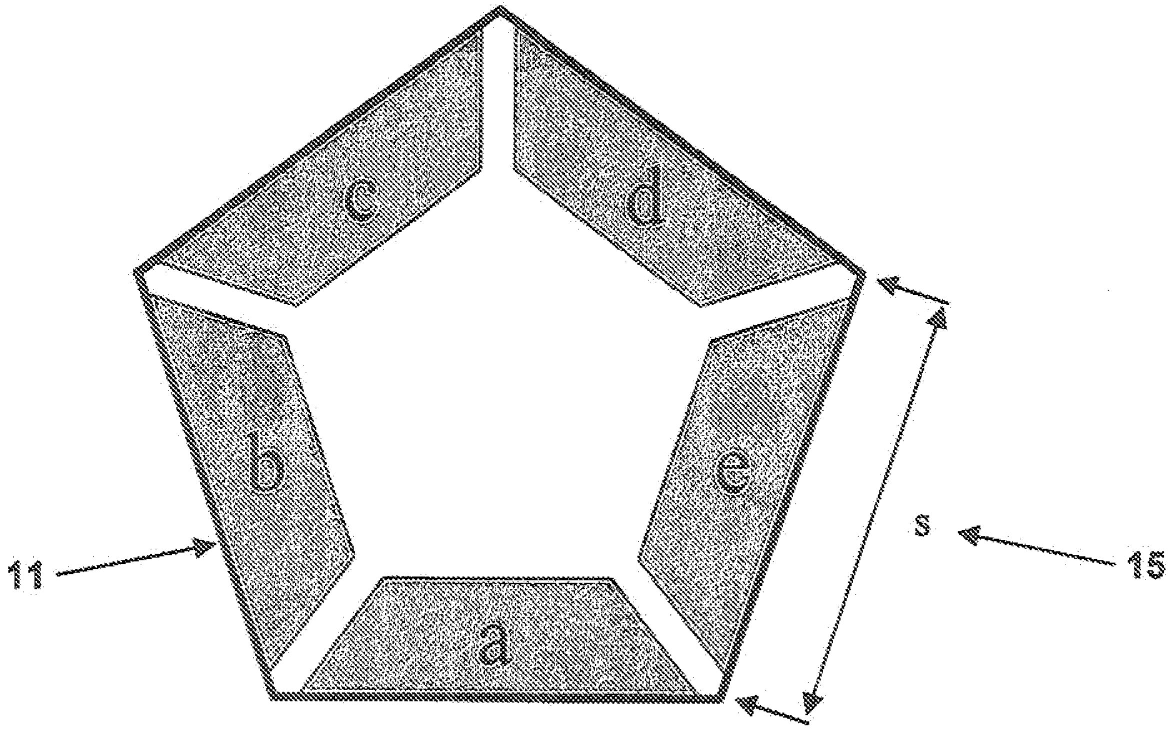

Figure 3a

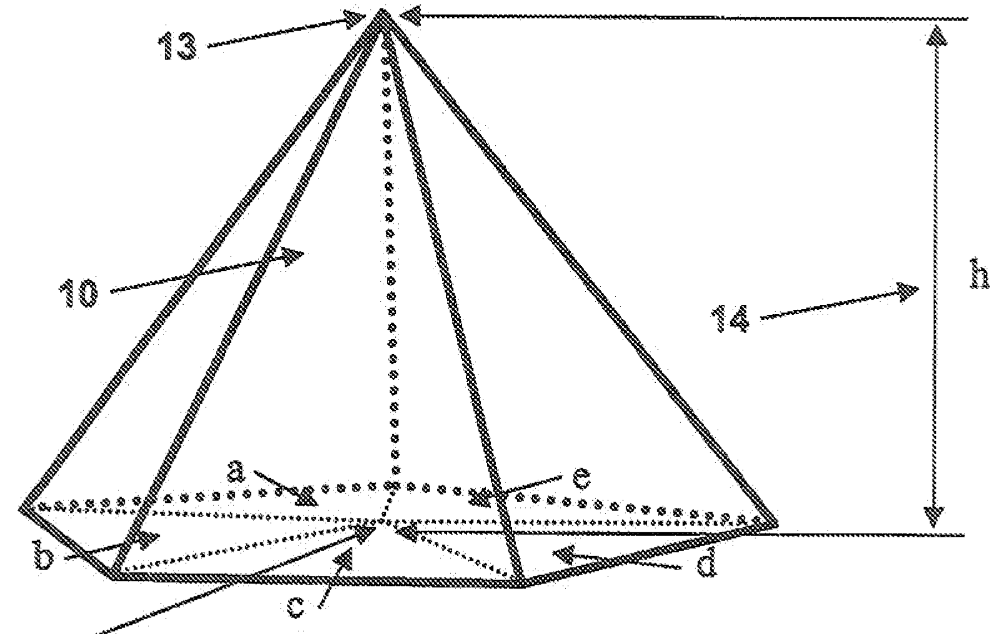

Figure 3b

Figure 3

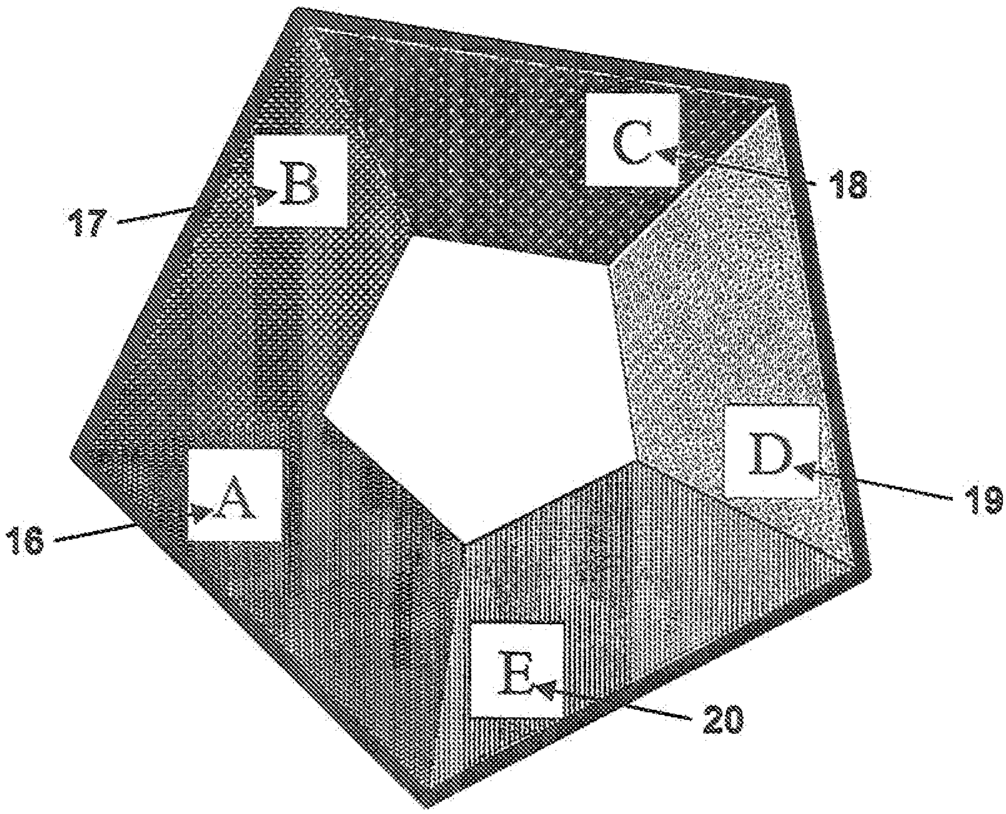

Figure 4

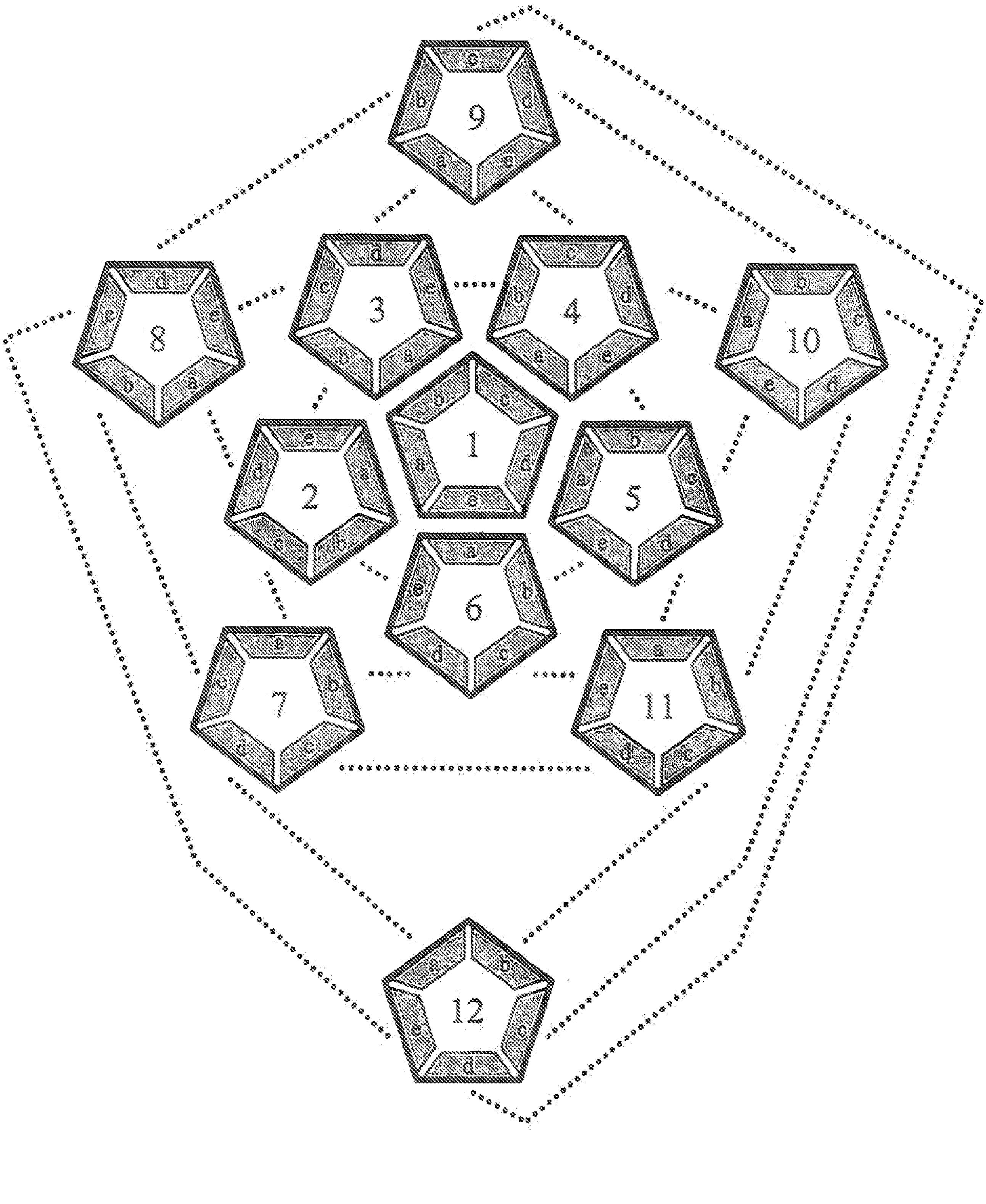

Figure 5

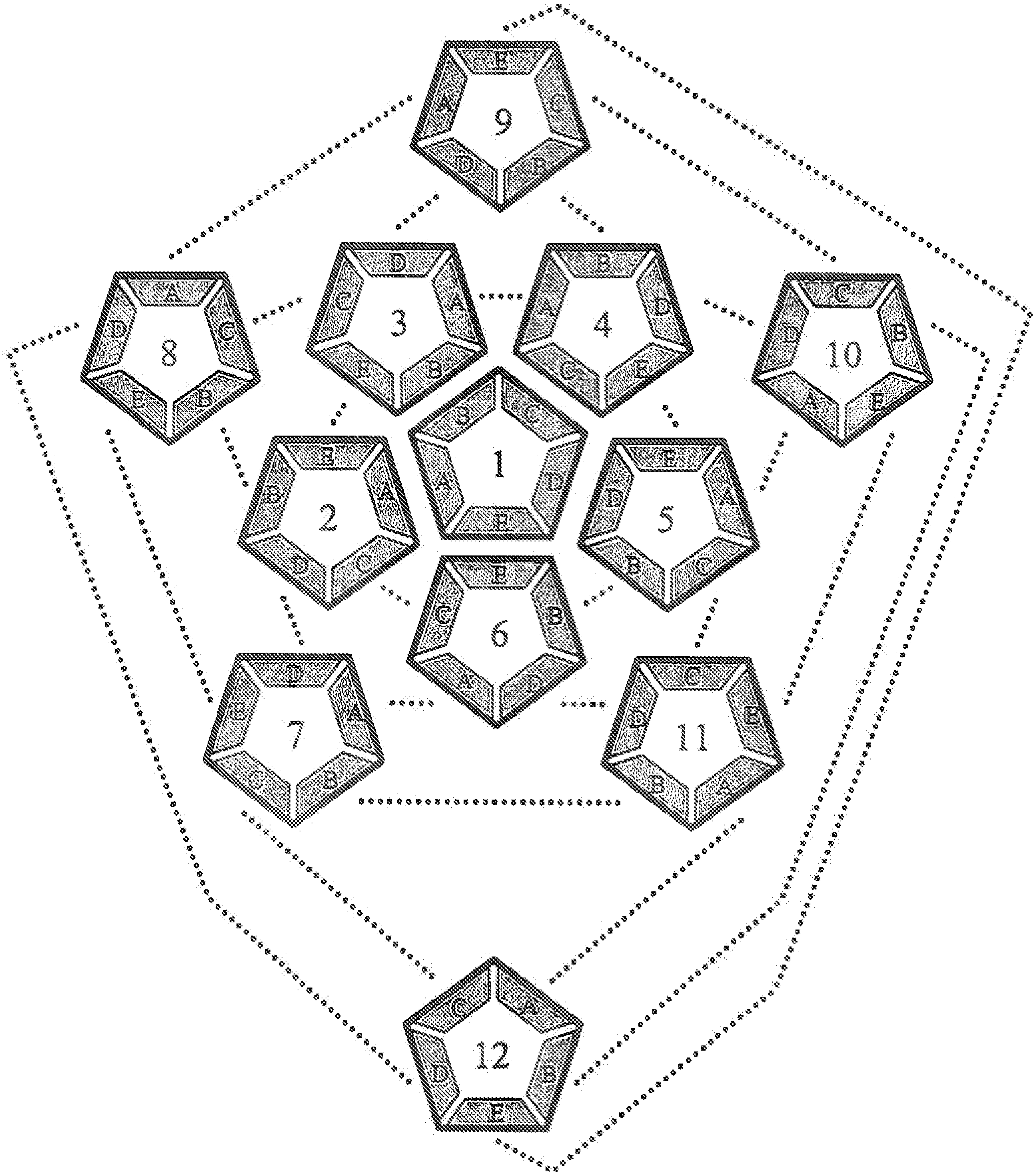

Figure 6

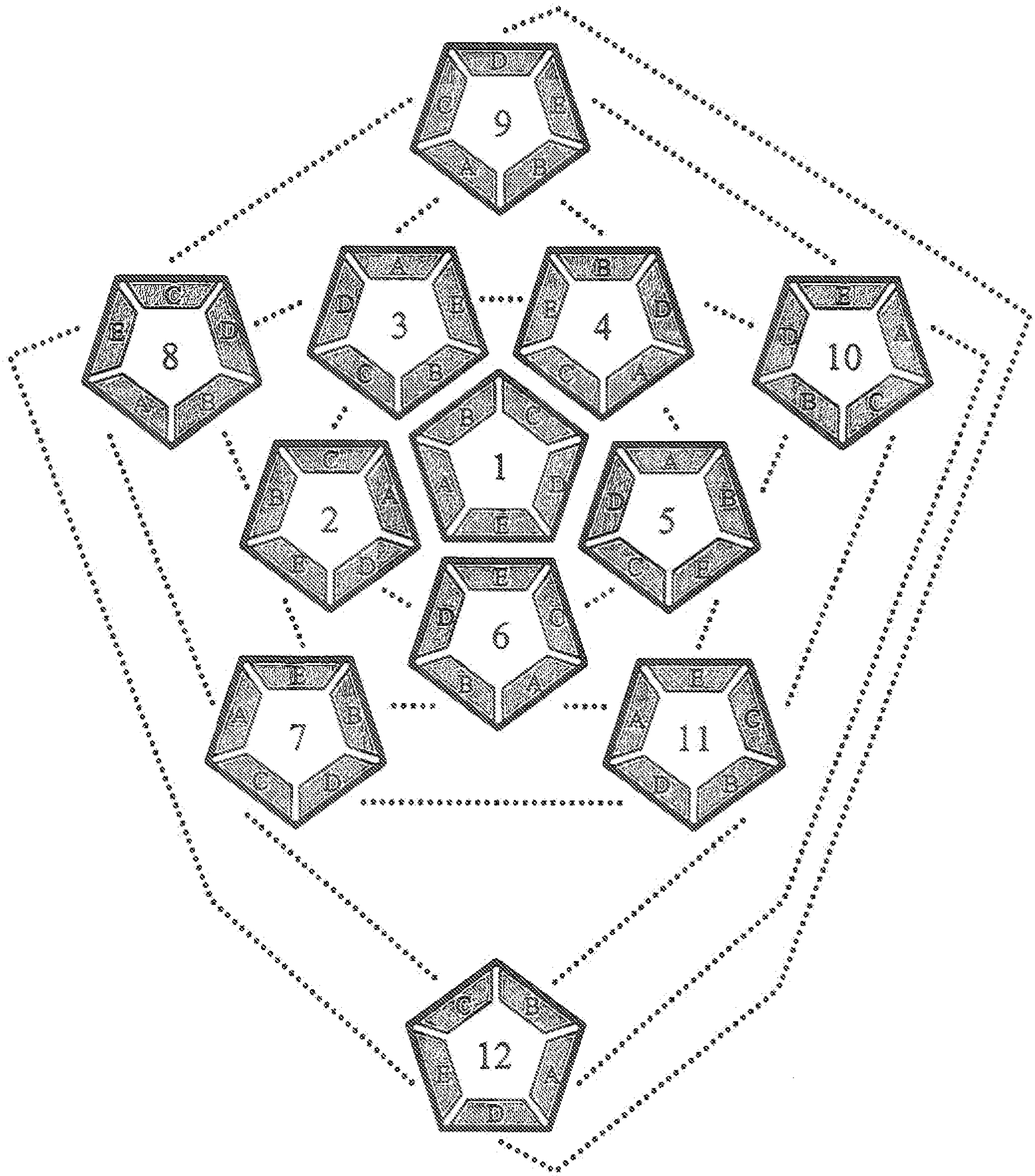
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Figure 7

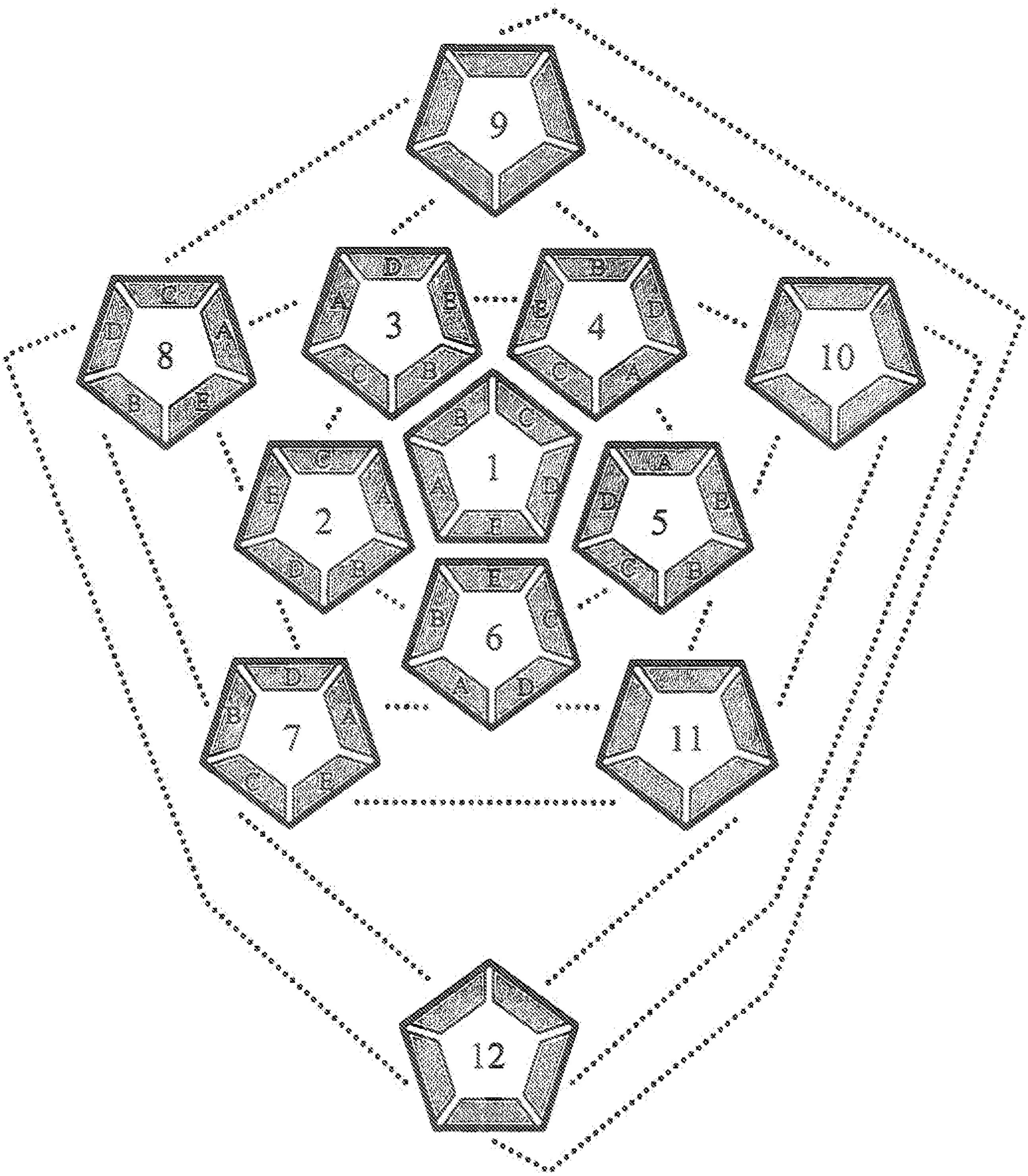


Figure 8

Adjacent Face	1	2	3	4	5	6	7	8	9	10	11	12
Face 1		1a	1b	1c	1d	1e						
Face 2	2a		2e			2b	2c	2d				
Face 3	3a	3b		3e				3c	3d			
Face 4	4a		4b		4e				4c	4d		
Face 5	5a			5b		5e				5c	5d	
Face 6	6a	6e			6b		6d				6c	
Face 7		7a				7b		7e			7c	7d
Face 8		8a	8e				8b		8d			8c
Face 9			9a	9e				9b		9d		9c
Face 10				10a	10e				10b		10d	10c
Face 11					11a	11e	11d			11b		11c
Face 12							12a	12e	12d	12c	12b	

Figure 9

Adjacent Face	1	2	3	4	5	6	7	8	9	10	11	12
Face 1		a A	b B	c C	d D	e E						
Face 2	a A		e E			b C	c D	d B				
Face 3	a B	b E		e A				c C	d D			
Face 4	a C		b A		e E				c B	d D		
Face 5	a D			b E		e B				c A	d C	
Face 6	a E	e C			b B		d A				c D	
Face 7		a D				b A		e E			c B	d C
Face 8		a B	e C				b E		d A			c D
Face 9			a D	e B				b A		d C		c E
Face 10				a D	e A				b C		d E	c B
Face 11					a C	e D	d B			b E		c A
Face 12							a C	e D	d E	c B	b A	

Figure 10

Adjacent Face	1	2	3	4	5	6	7	8	9	10	11	12
Face 1		a A	b B	c C	d D	e E						
Face 2	a A		e C			b D	c E	d B				
Face 3	a B	b C		e E				c D	d A			
Face 4	a C		b E		e A				c B	d D		
Face 5	a D			b A		e C				c B	d E	
Face 6	a E	e D			b C		d B				c A	
Face 7		a E				b B		e A			c D	d C
Face 8		a B	e D				b A		d C			c E
Face 9			a A	e B				b C		d E		c D
Face 10				a D	e B				b E		d C	c A
Face 11					a E	e A	d D			b C		c B
Face 12							a C	e E	d D	c A	b B	

Figure 11

Adjacent Face	1	2	3	4	5	6	7	8	9	10	11	12
Face 1		a A	b B	c C	d D	e E						
Face 2	a A		e C			b B	c D	d E				
Face 3	a B	b C		e E				c A	d D			
Face 4	a C		b E		e A				c B	d D		
Face 5	a D			b A		e C				c E	d B	
Face 6	a E	e B			b C		d A				c D	
Face 7		a D				b A		e B			c E	d C
Face 8		a E	e A				b B		d C			c D
Face 9			a D	e B				b C		d		c
Face 10				a D	e E				b		d	c
Face 11					a B	e D	d E			b		c
Face 12							a C	e D	d	c	b	

Figure 12

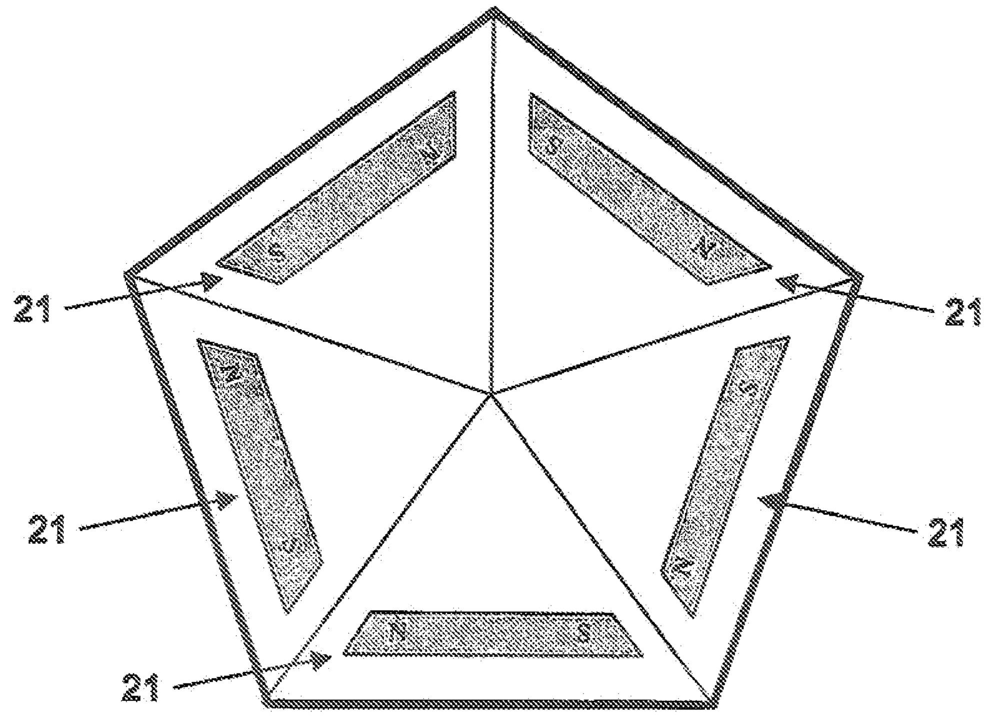


Figure 13a

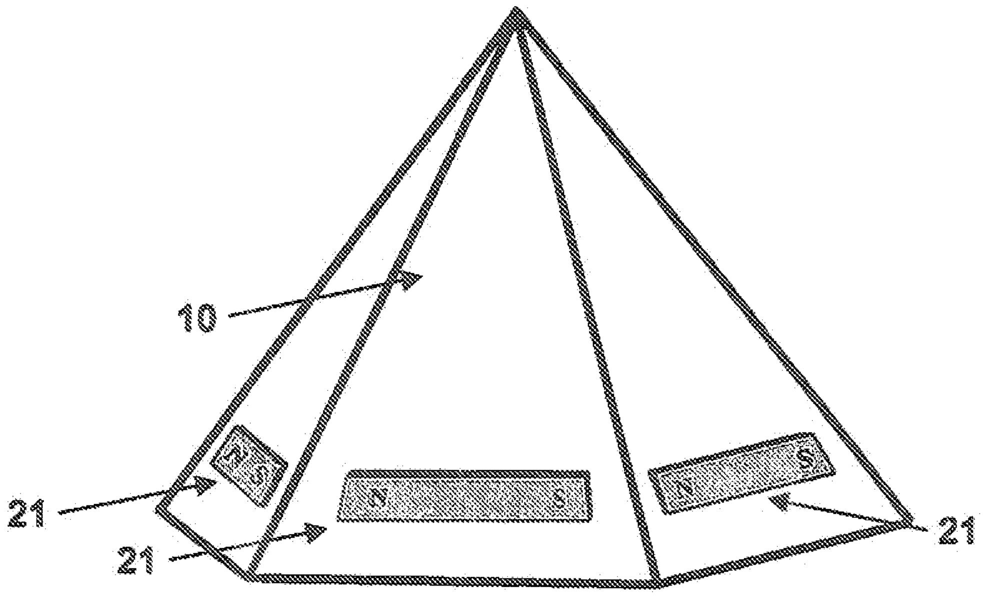


Figure 13b

Figure 13

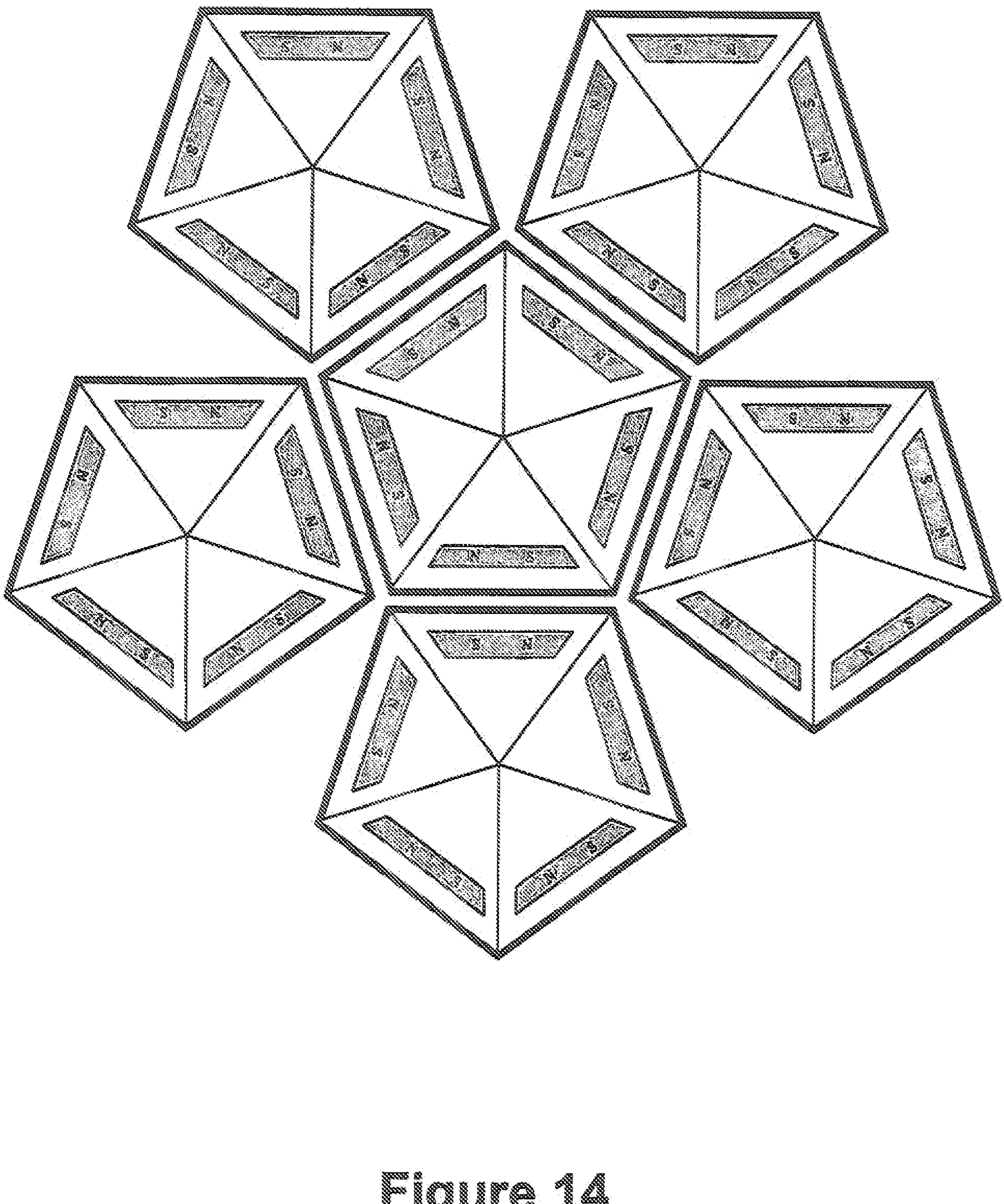


Figure 14

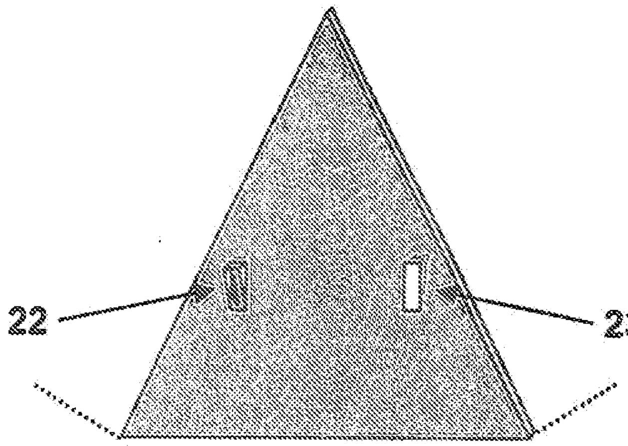


Figure 15a

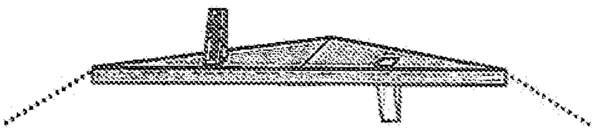


Figure 15b

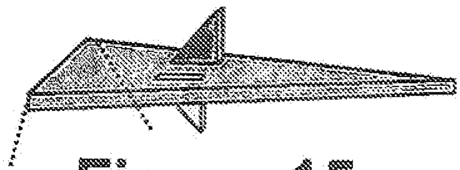


Figure 15c

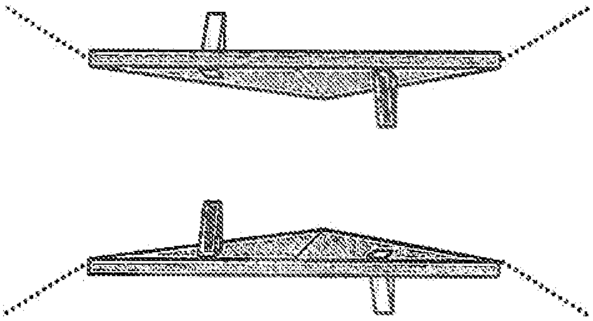


Figure 15d

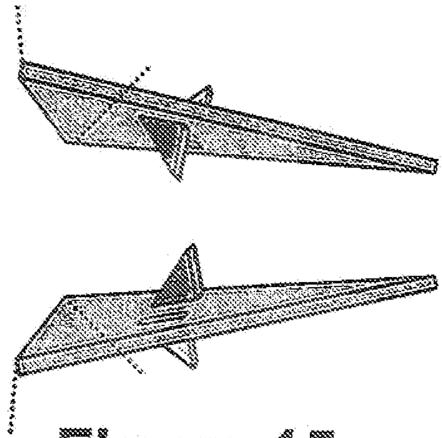


Figure 15e

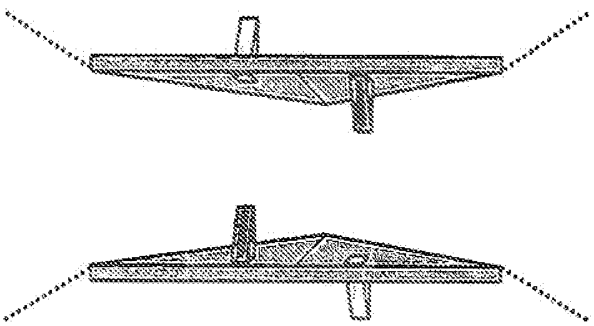


Figure 15f

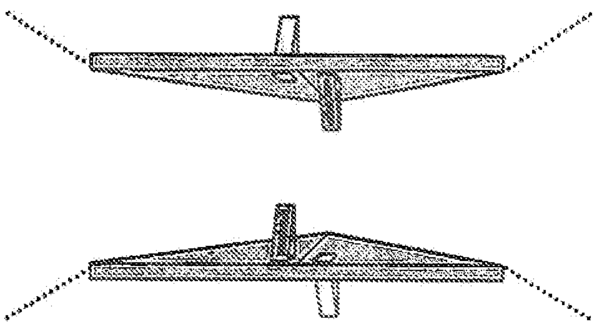
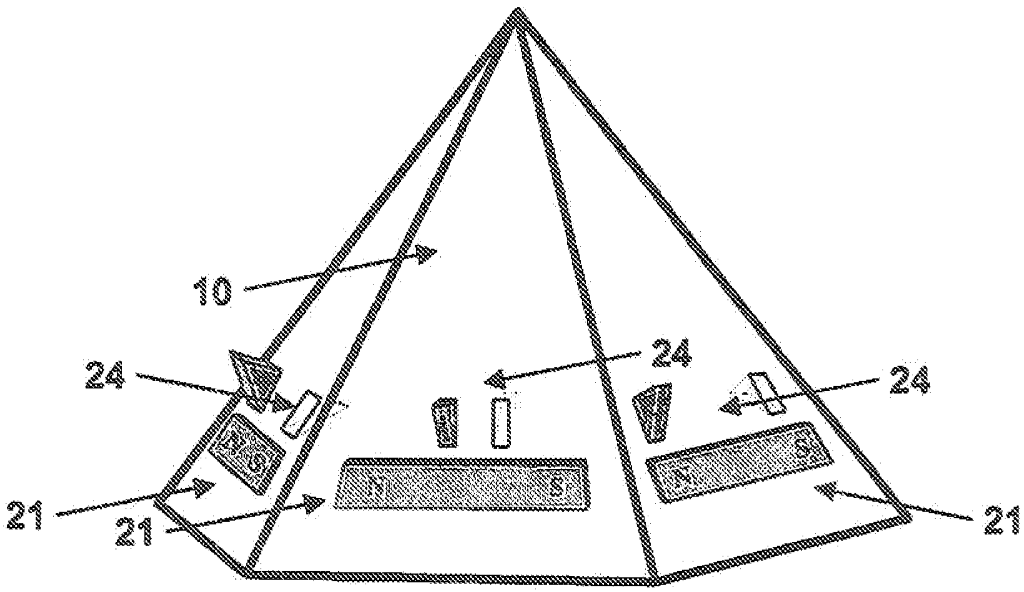


Figure 15g

Figure 15



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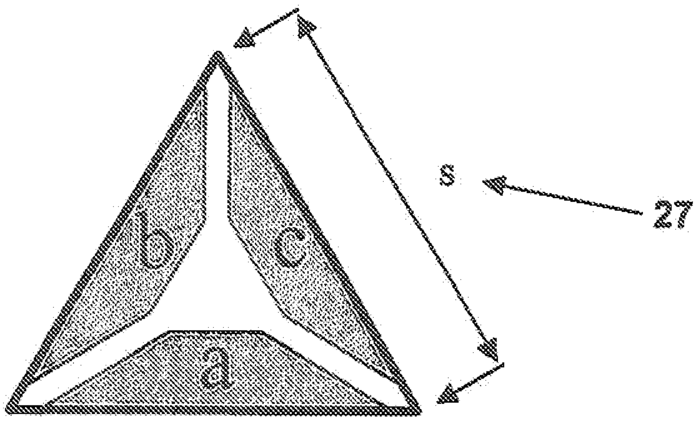

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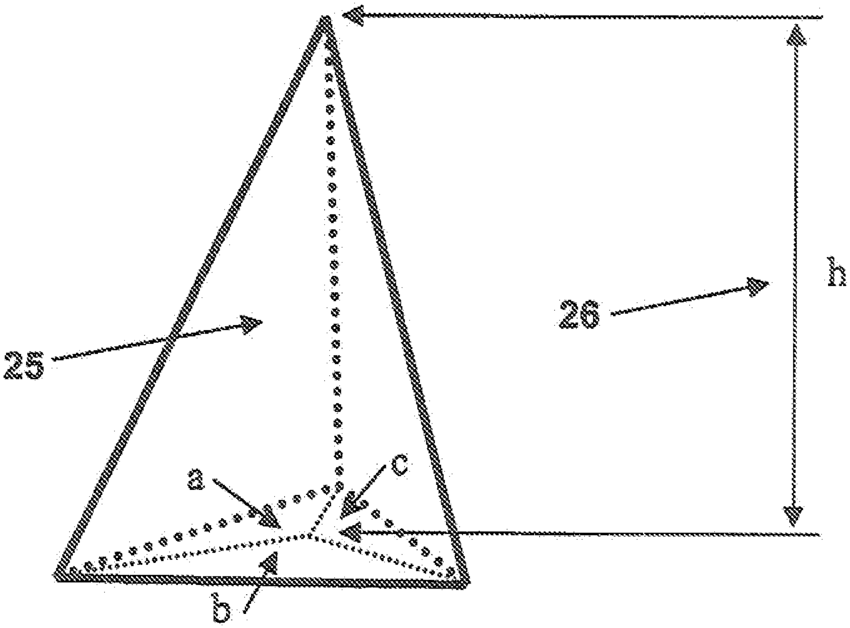
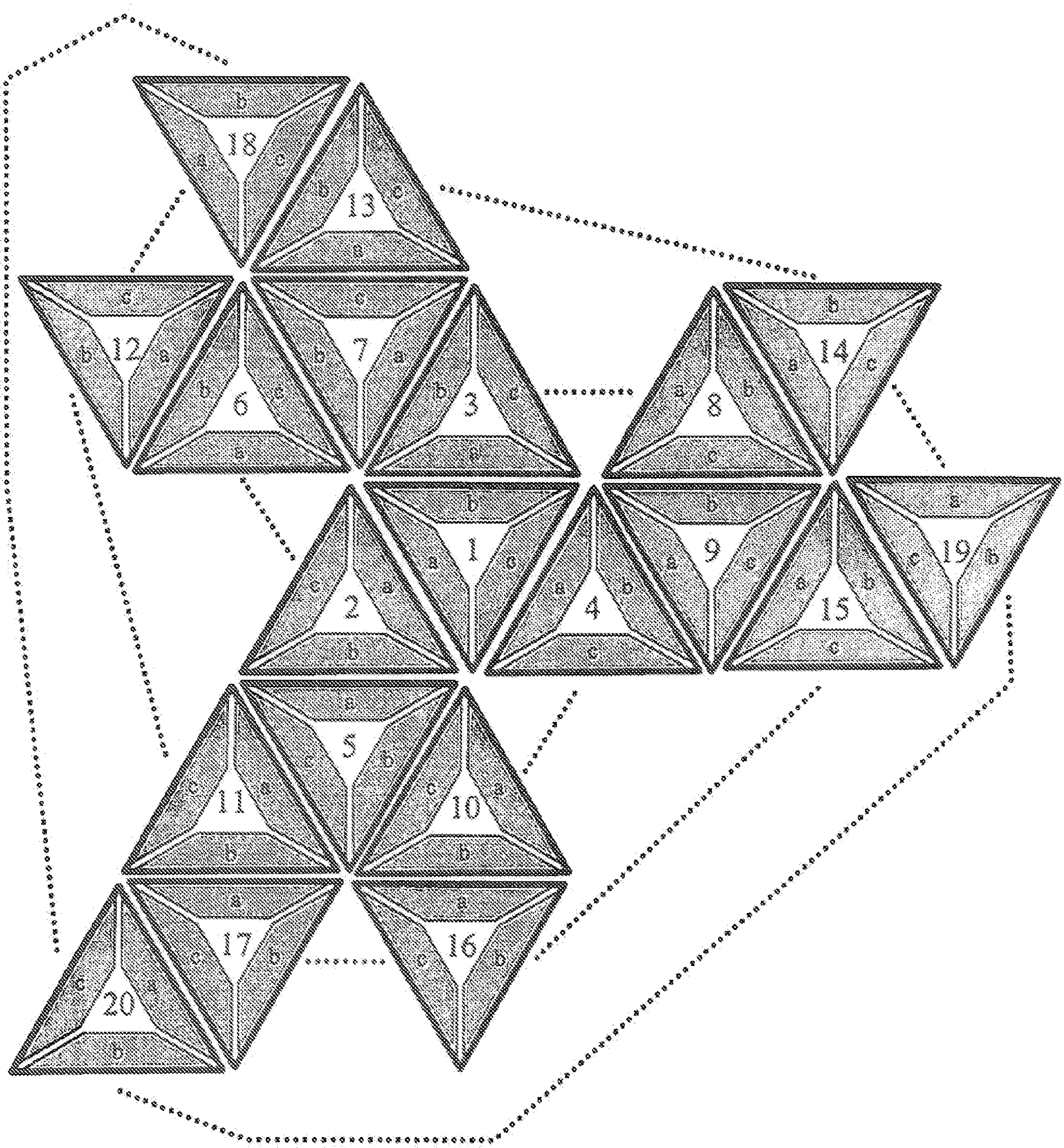


Figure 17b

Figure 17



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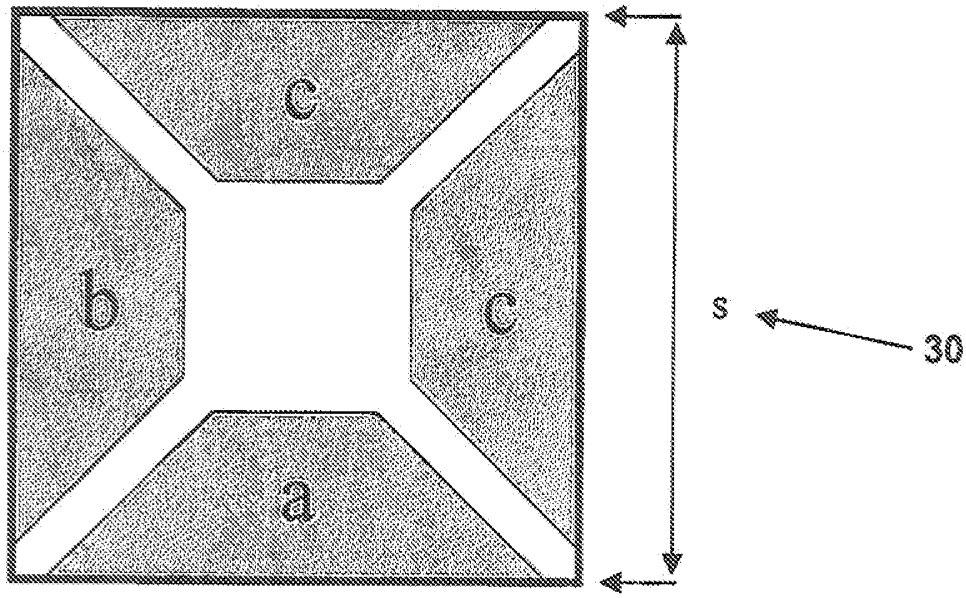

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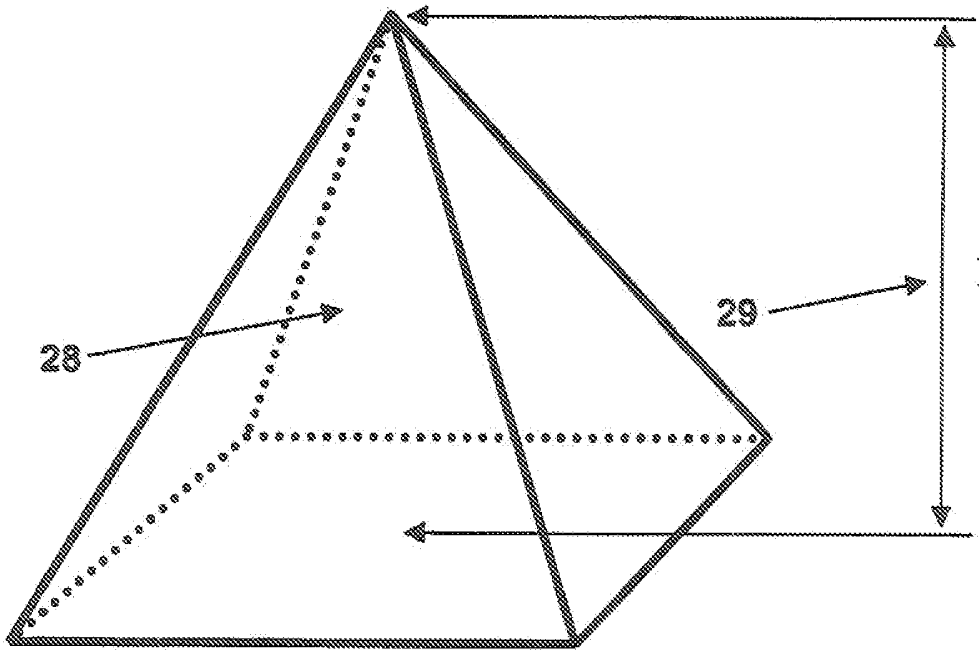
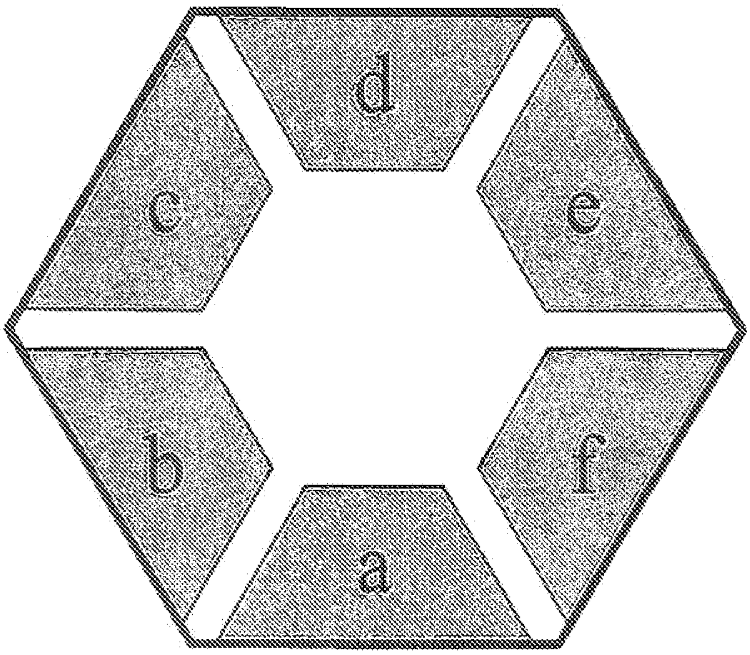


Figure 19b

Figure 19



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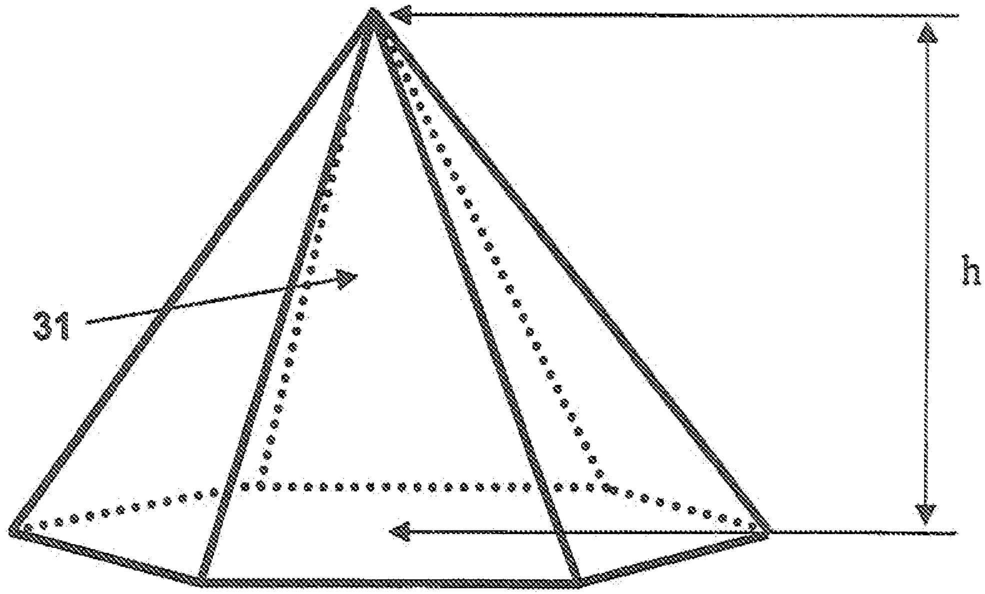
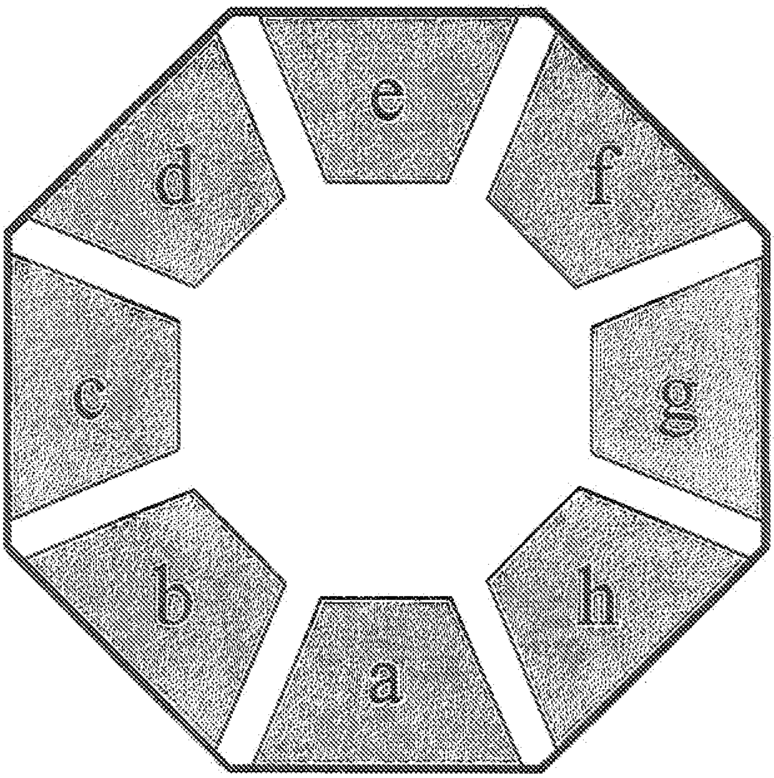


Figure 20b

Figure 20



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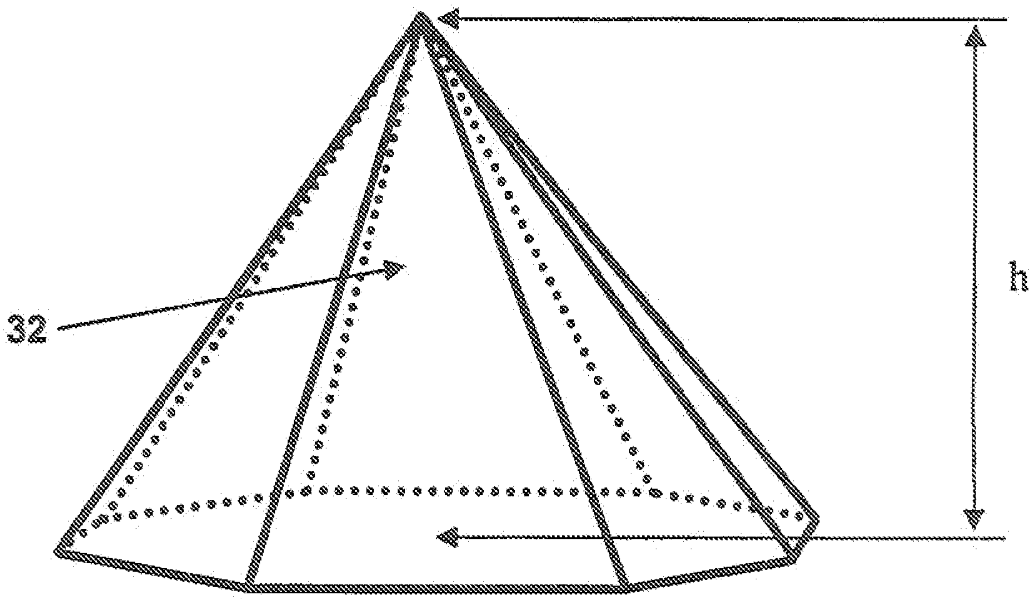


Figure 21b

Figure 21

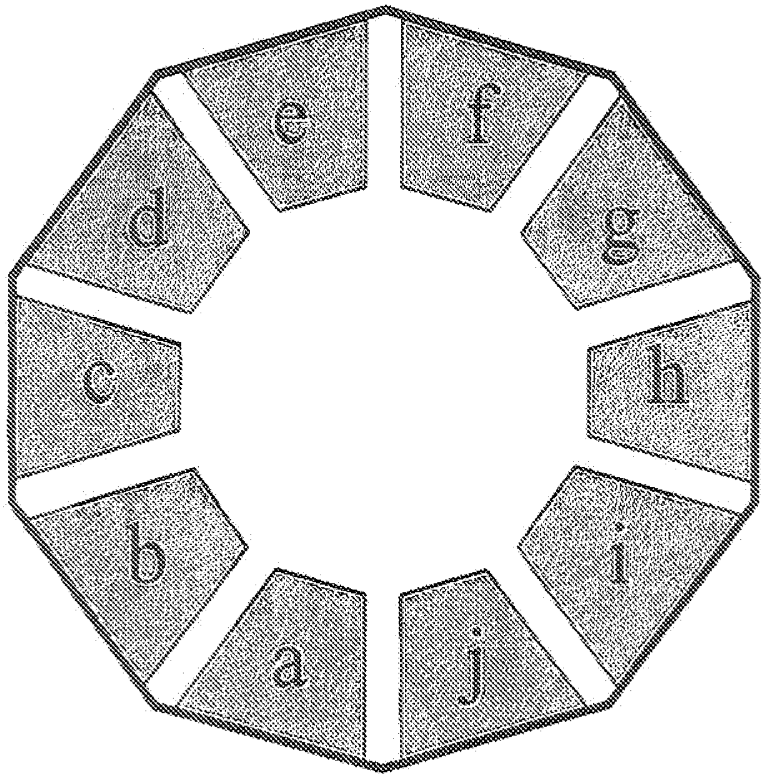


Figure 22a

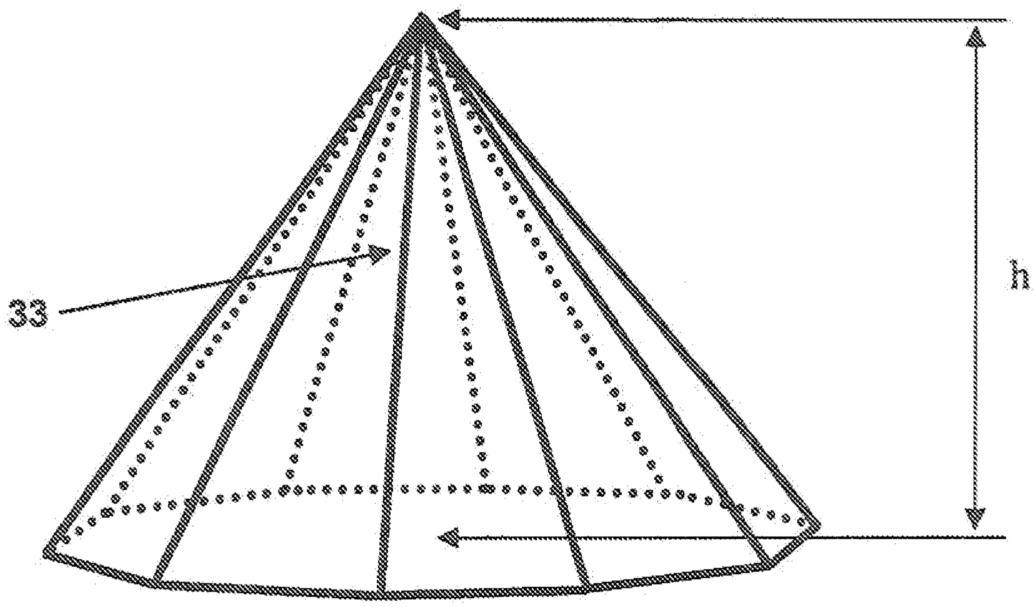
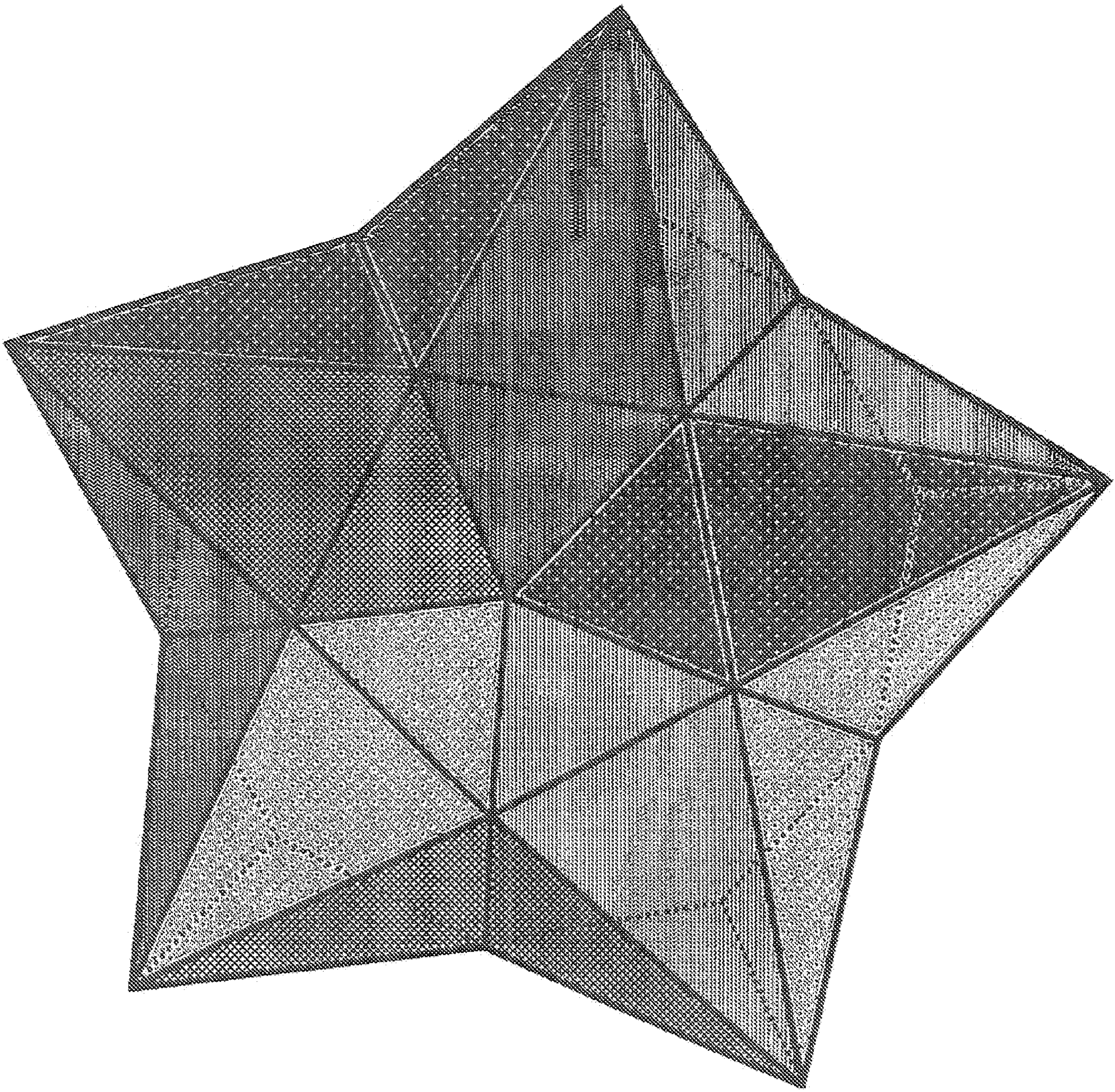


Figure 22b

Figure 22



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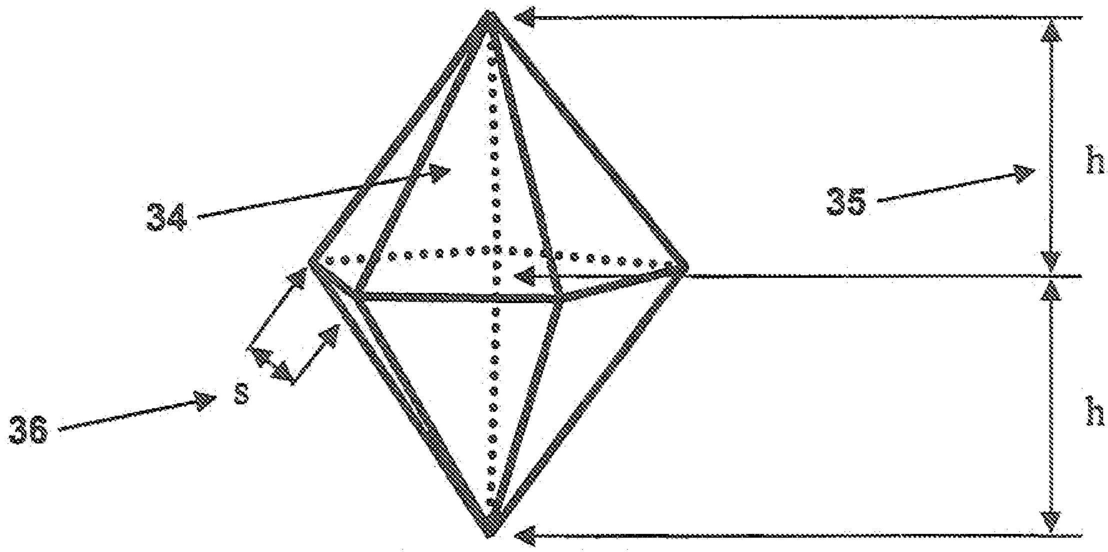

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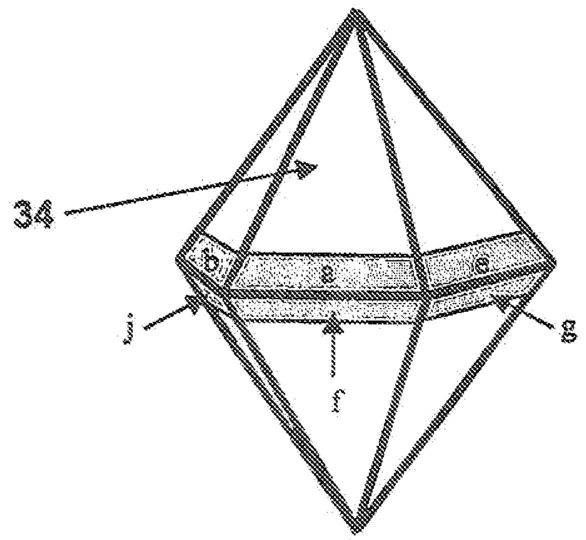
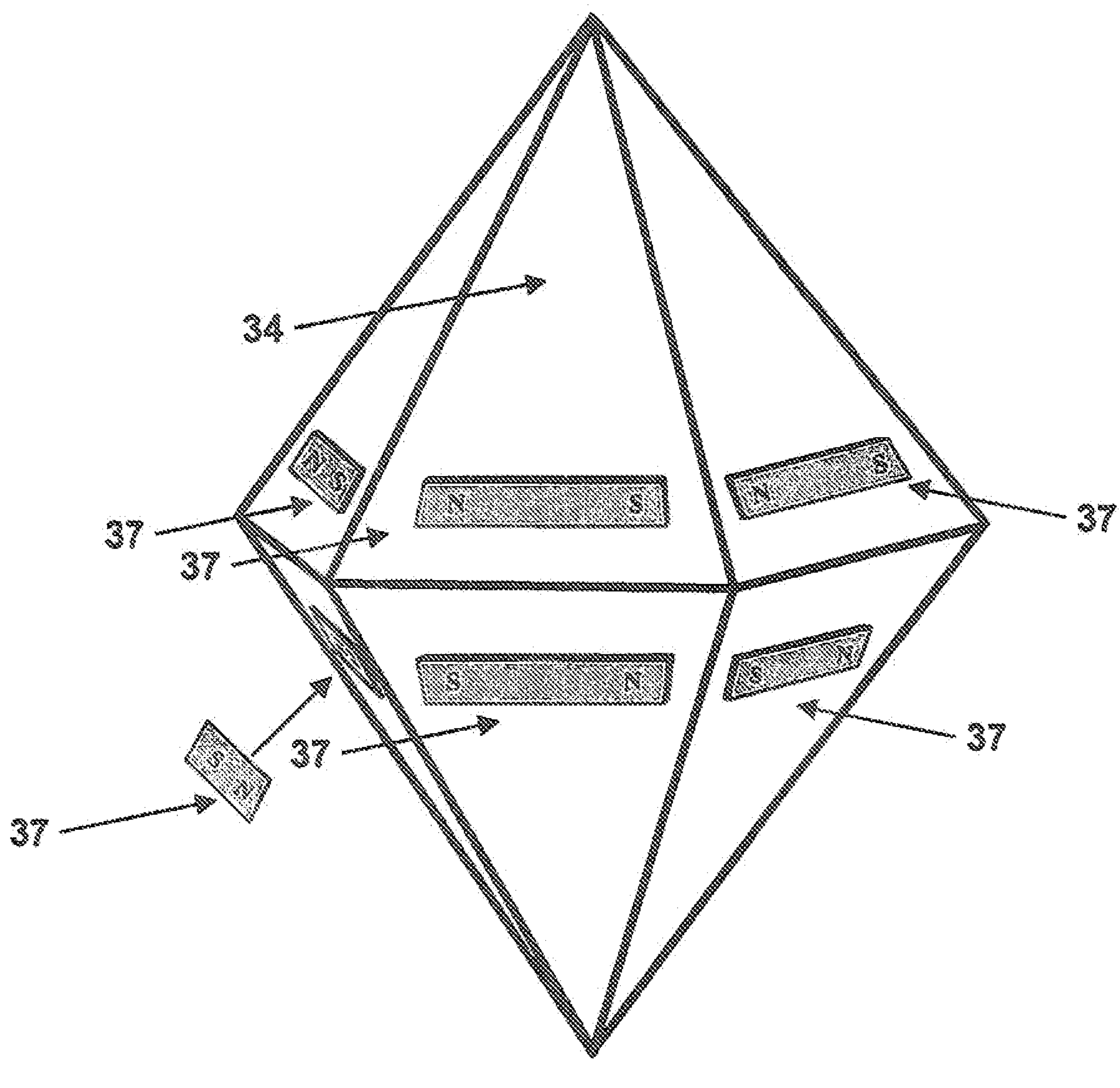


Figure 24b

Figure 24



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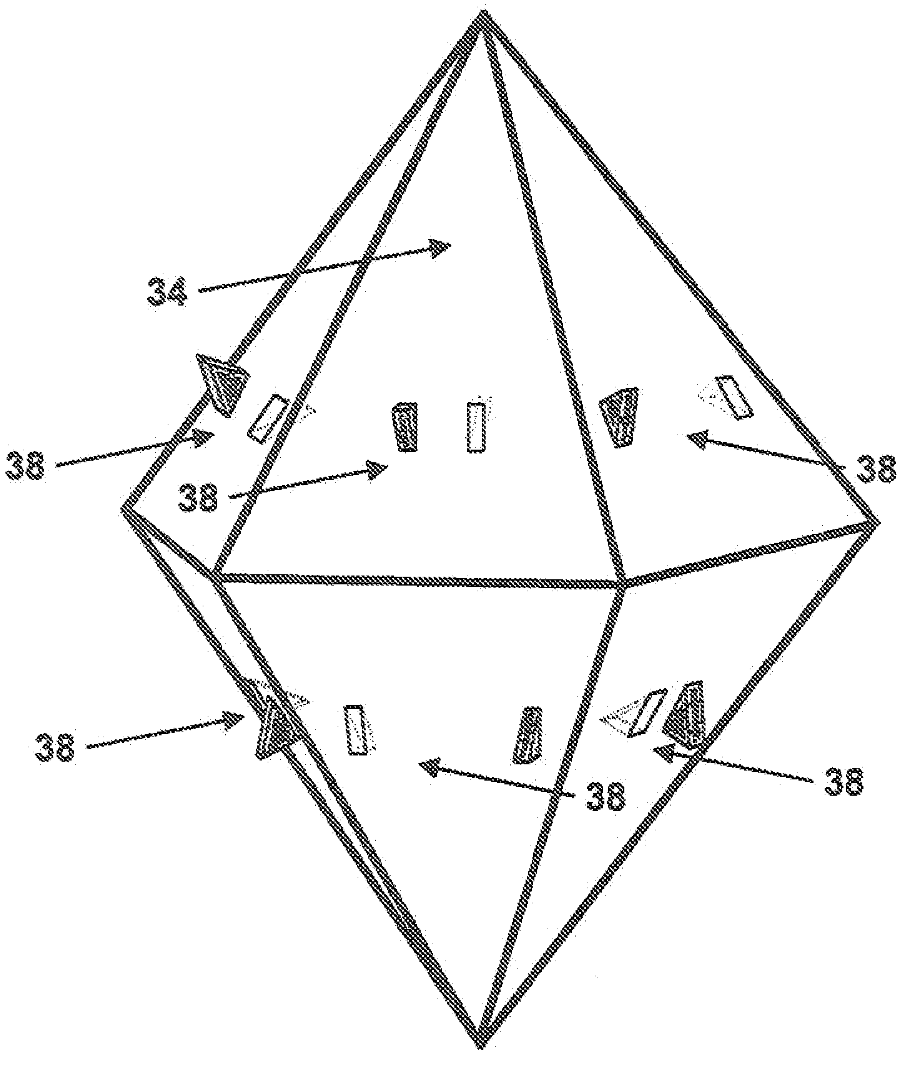

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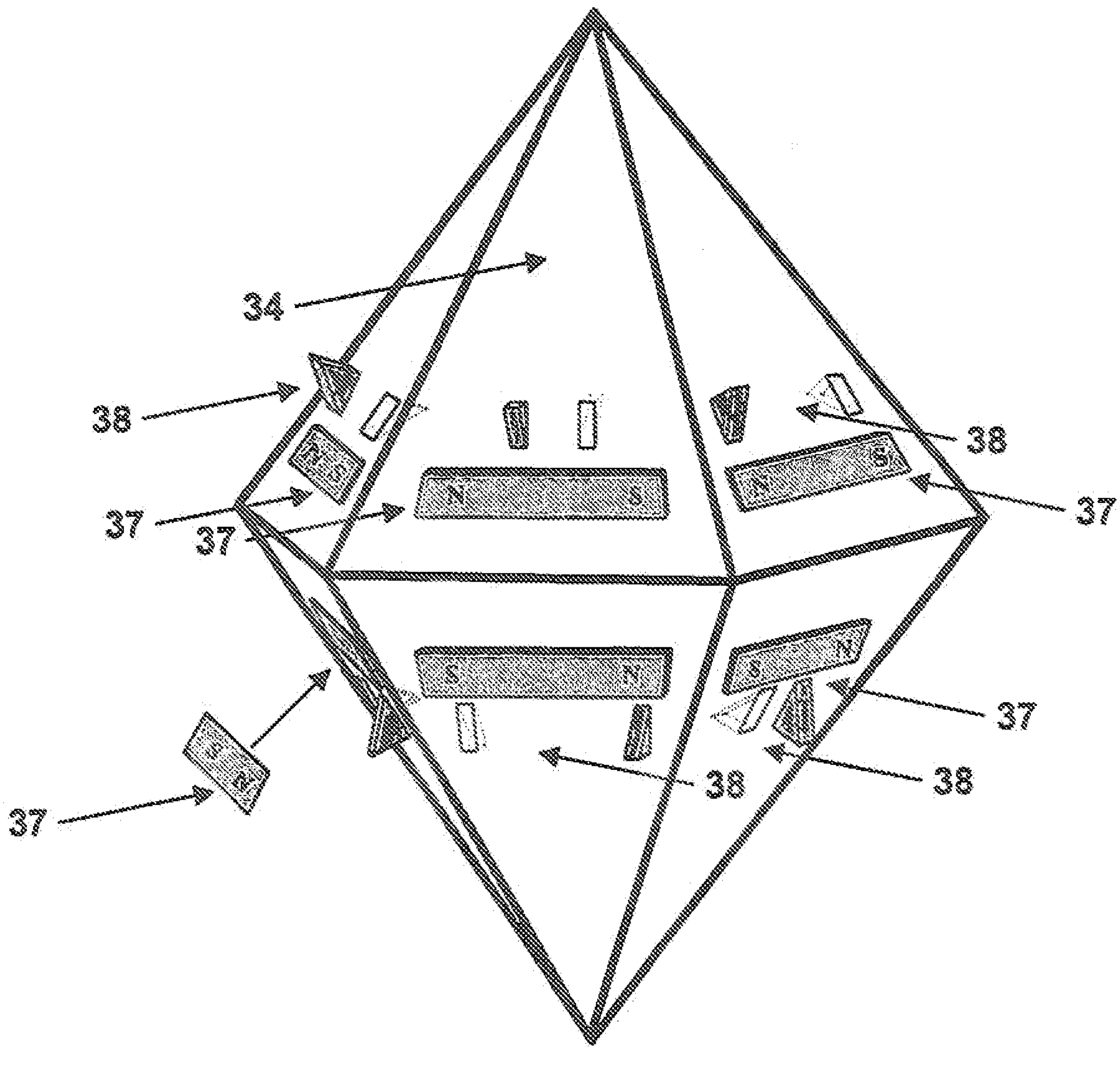

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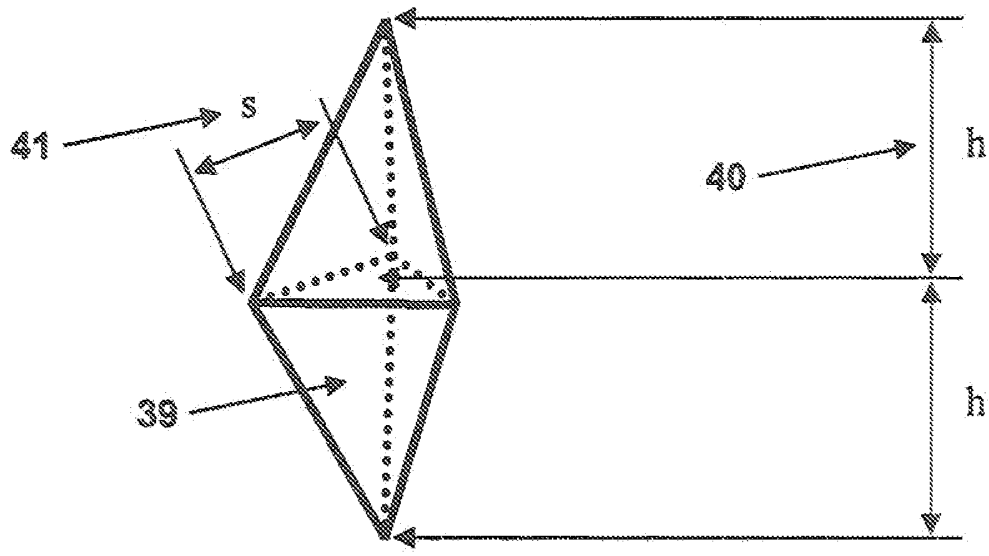

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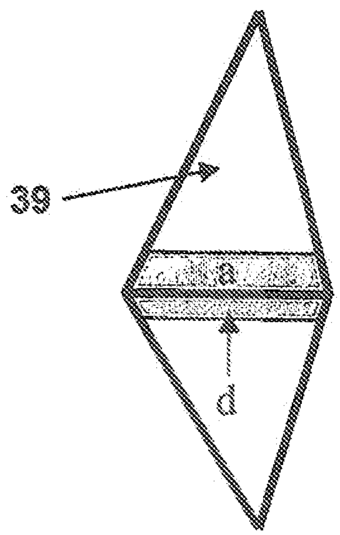
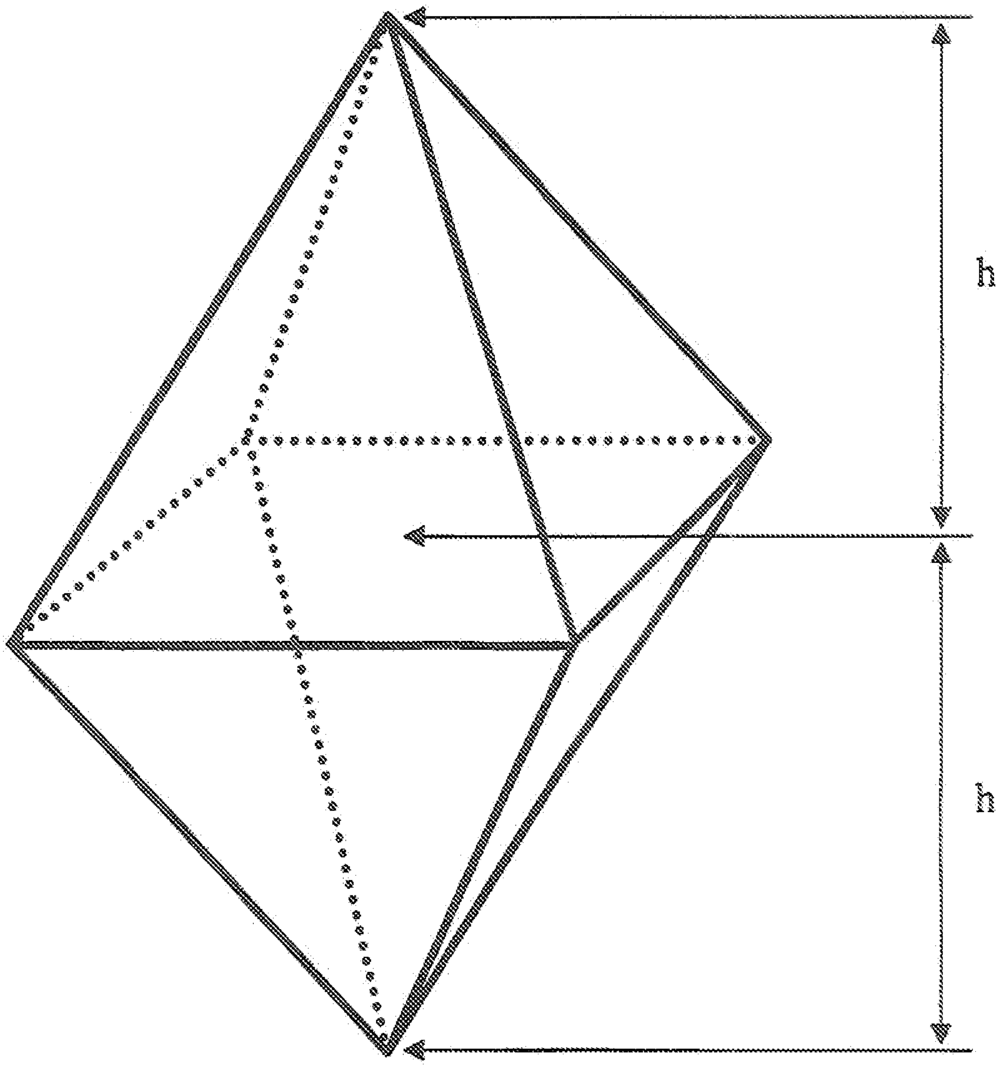


Figure 28b

Figure 28



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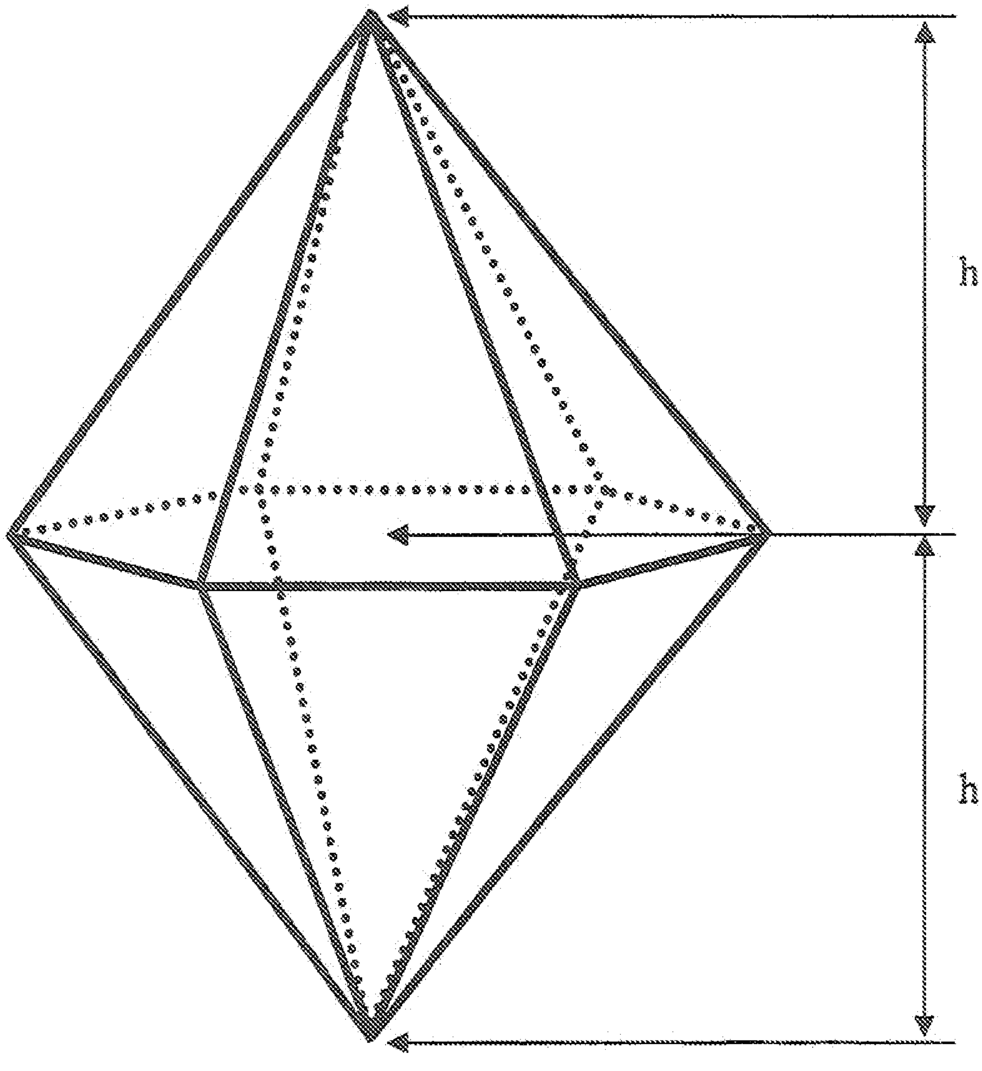

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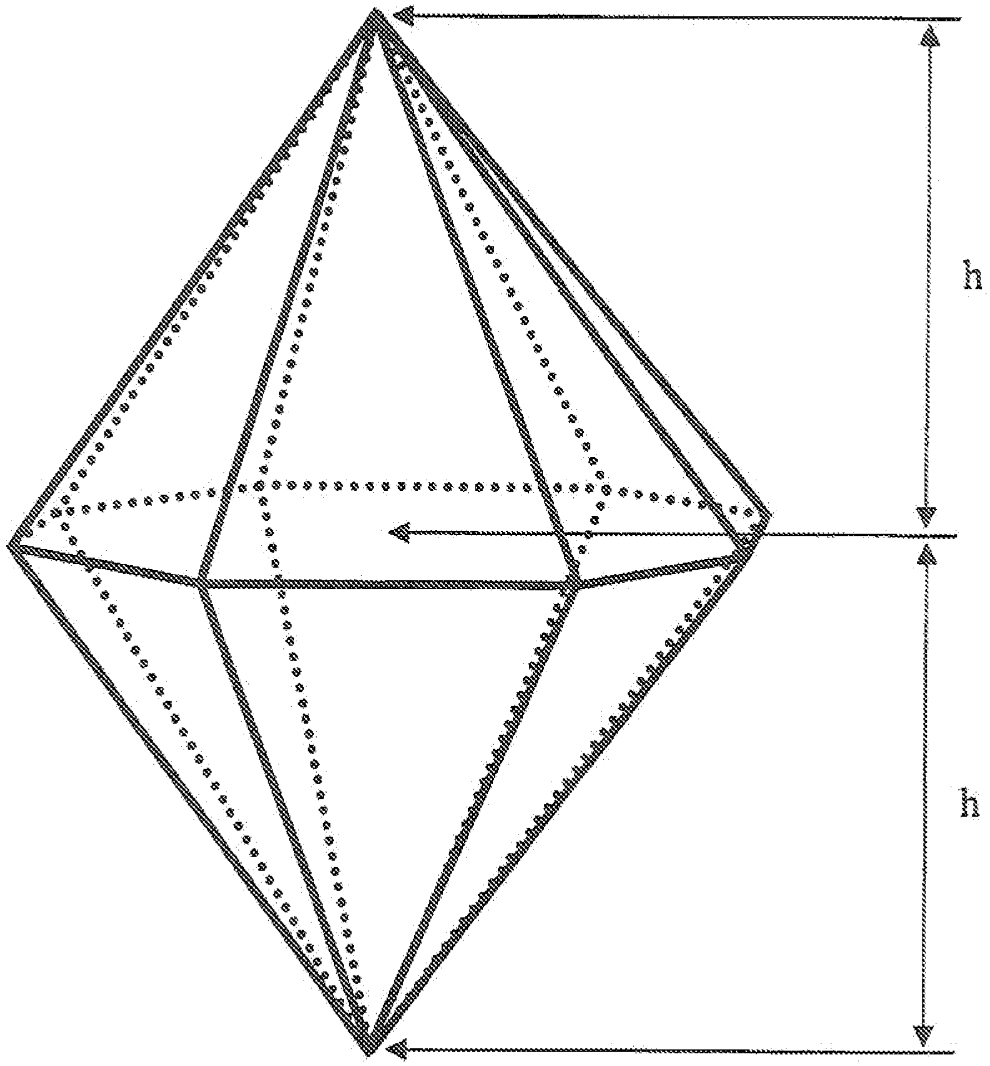

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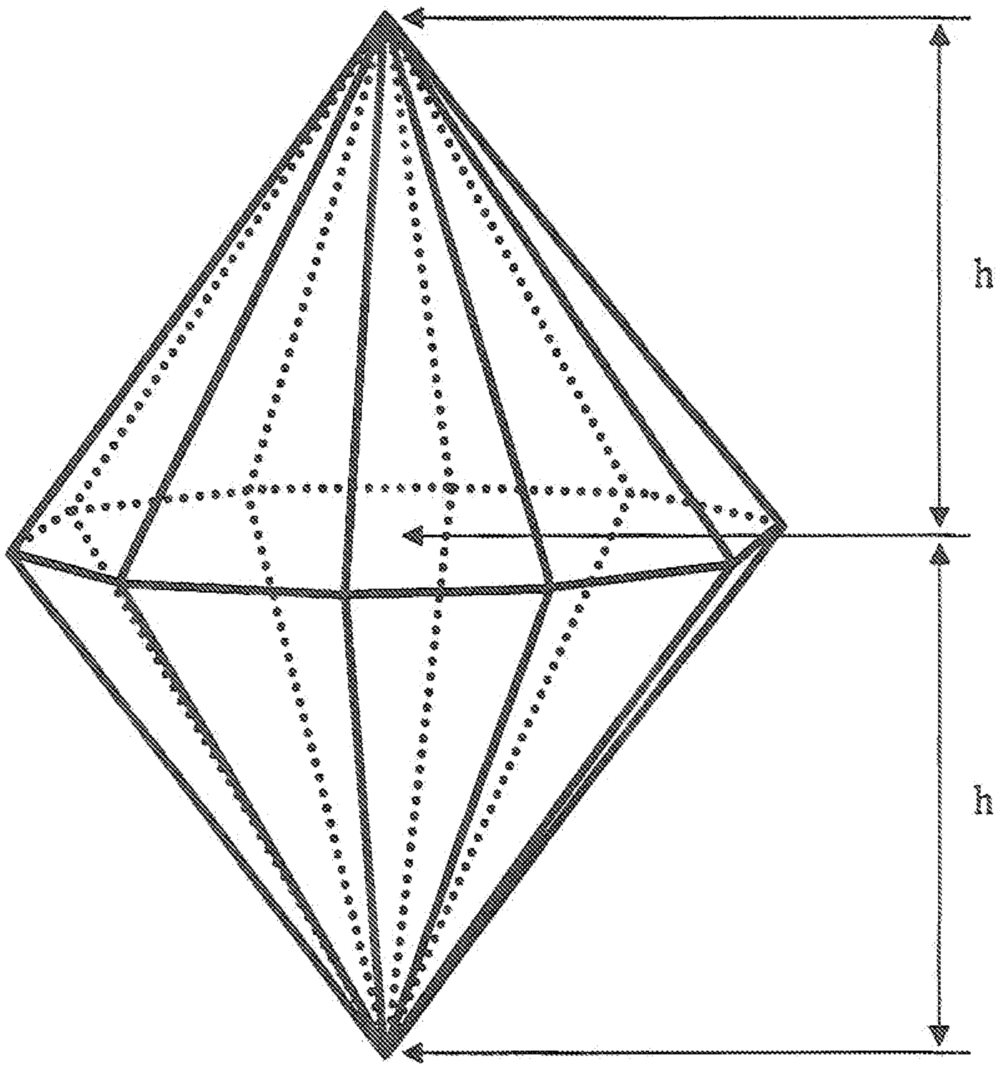

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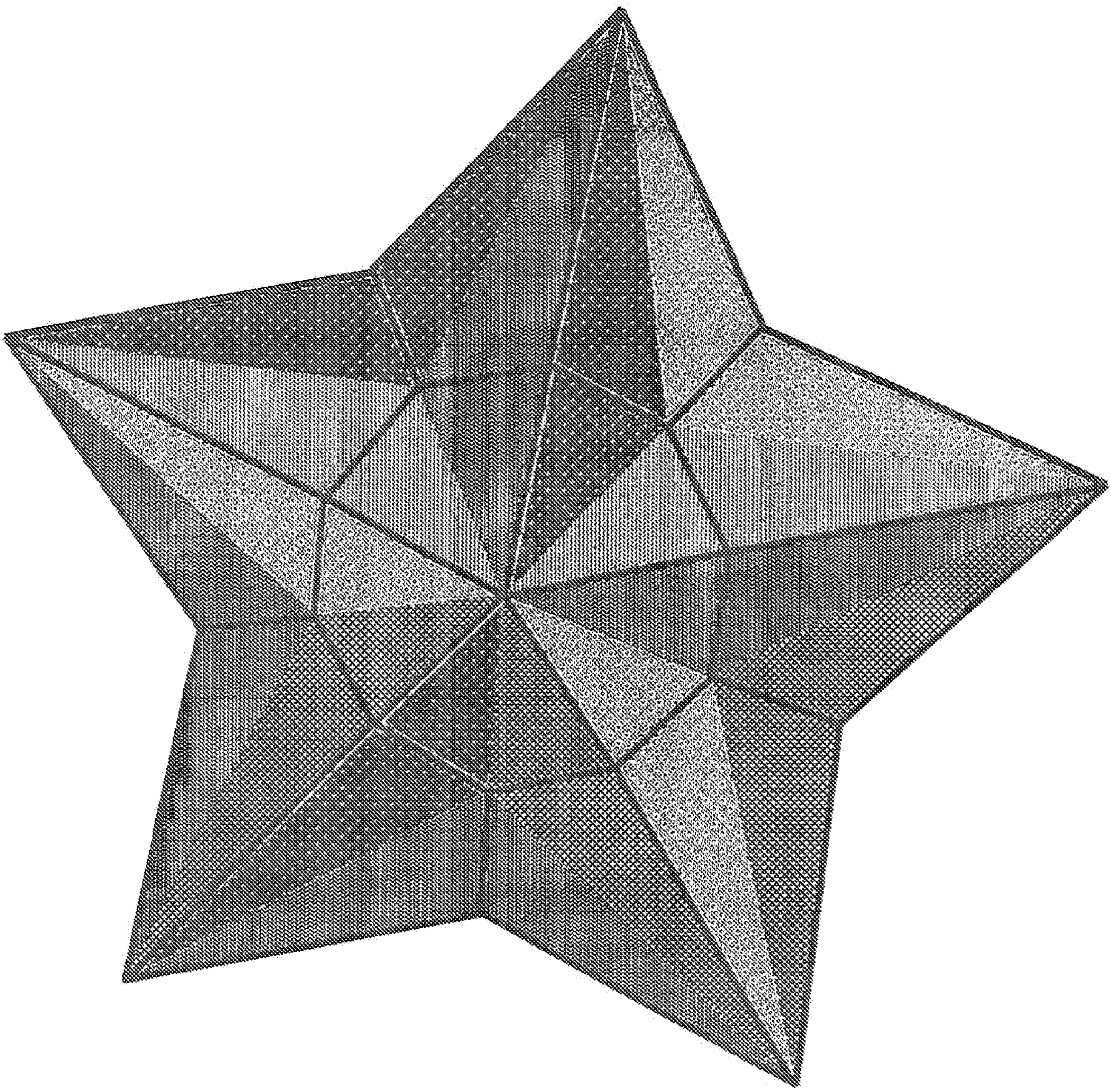

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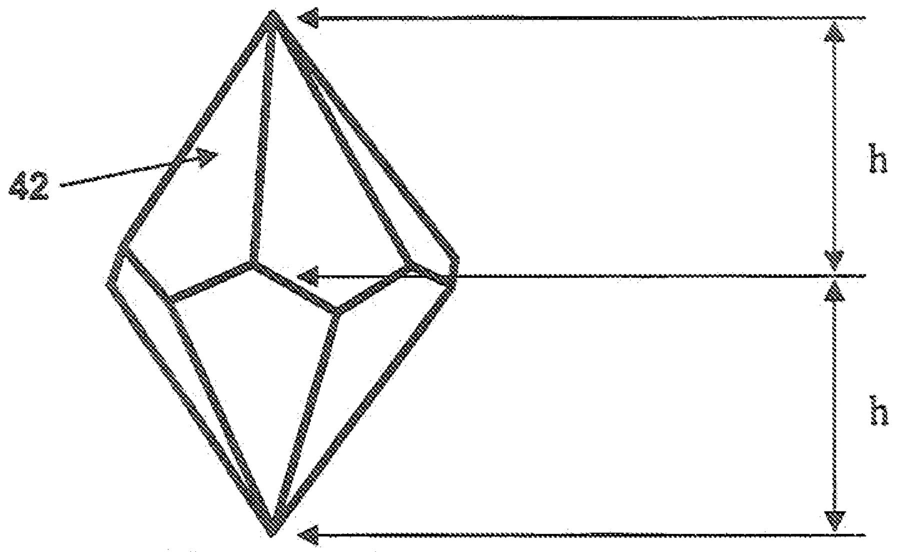

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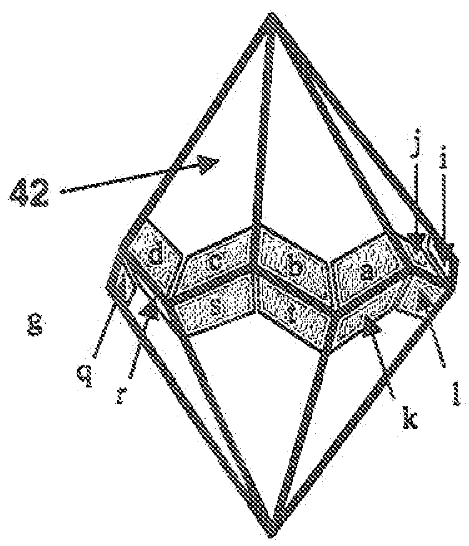
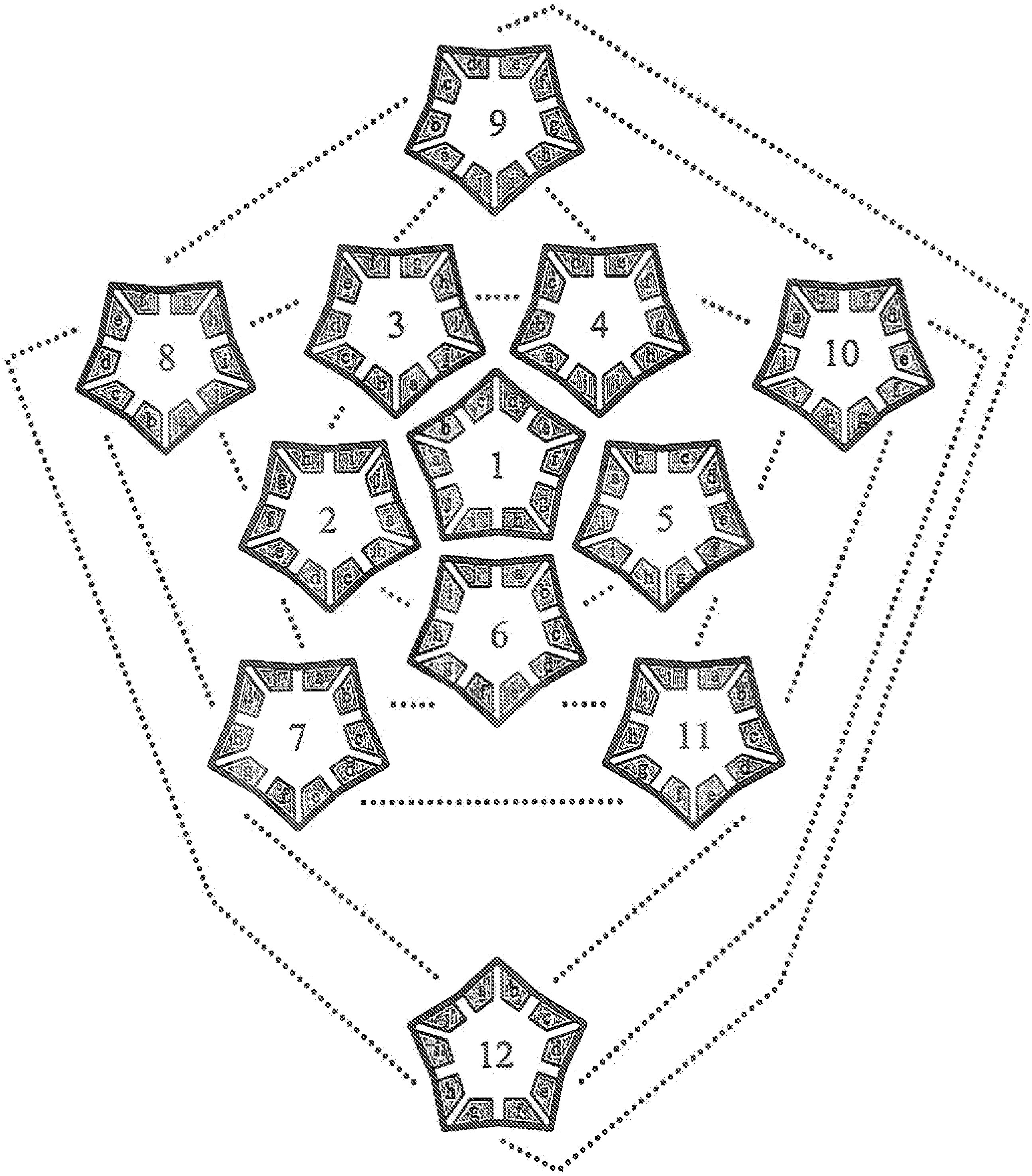


Figure 34b

Figure 34



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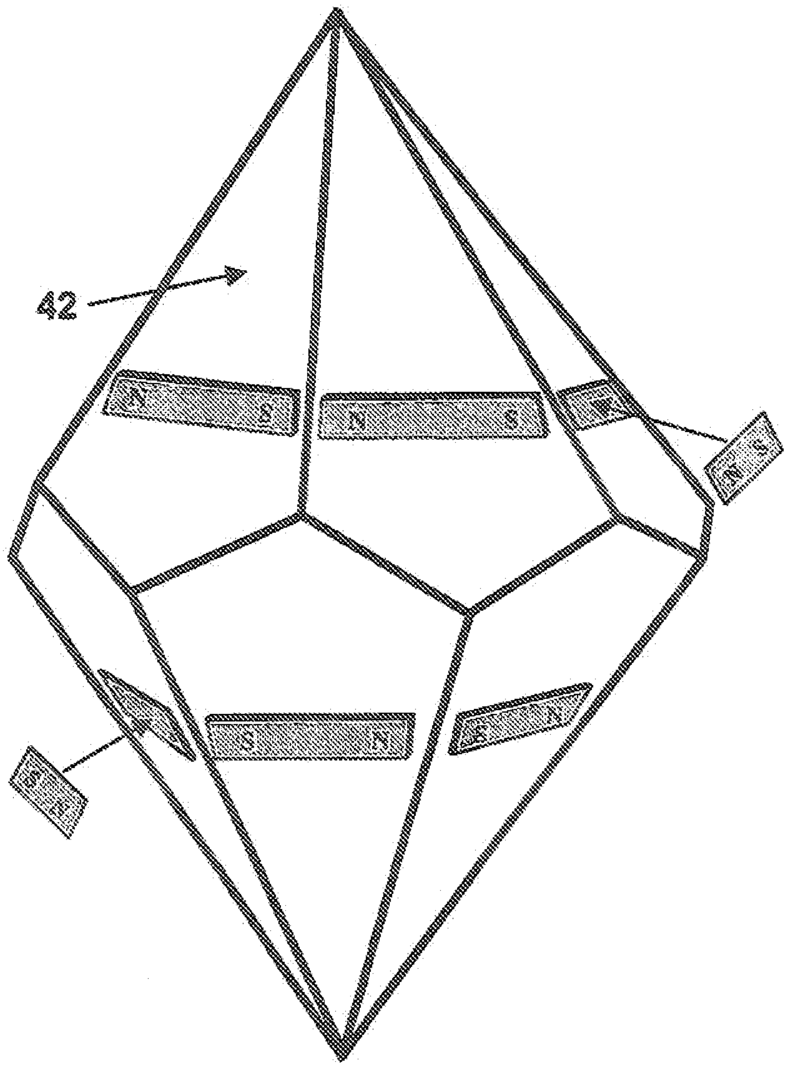

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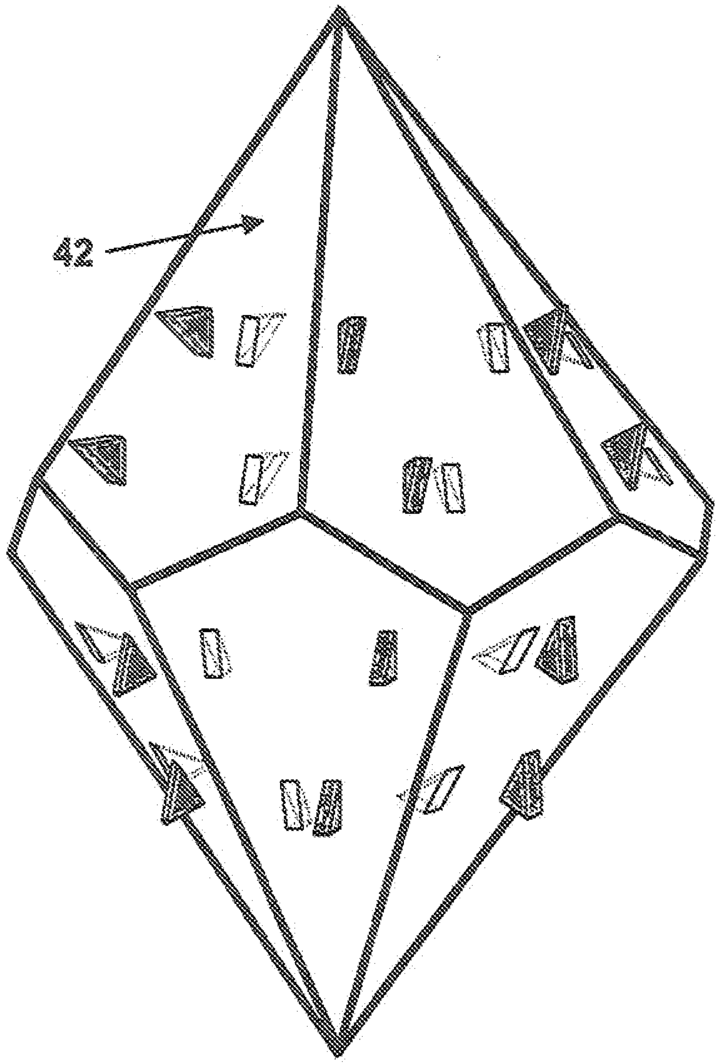

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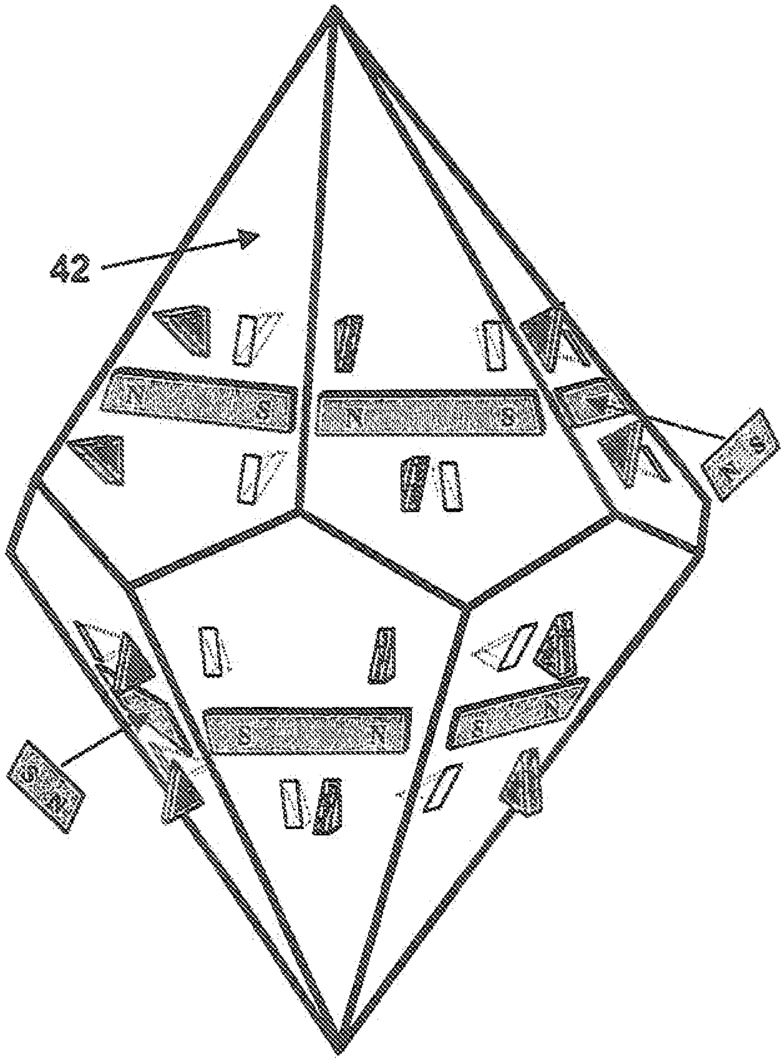

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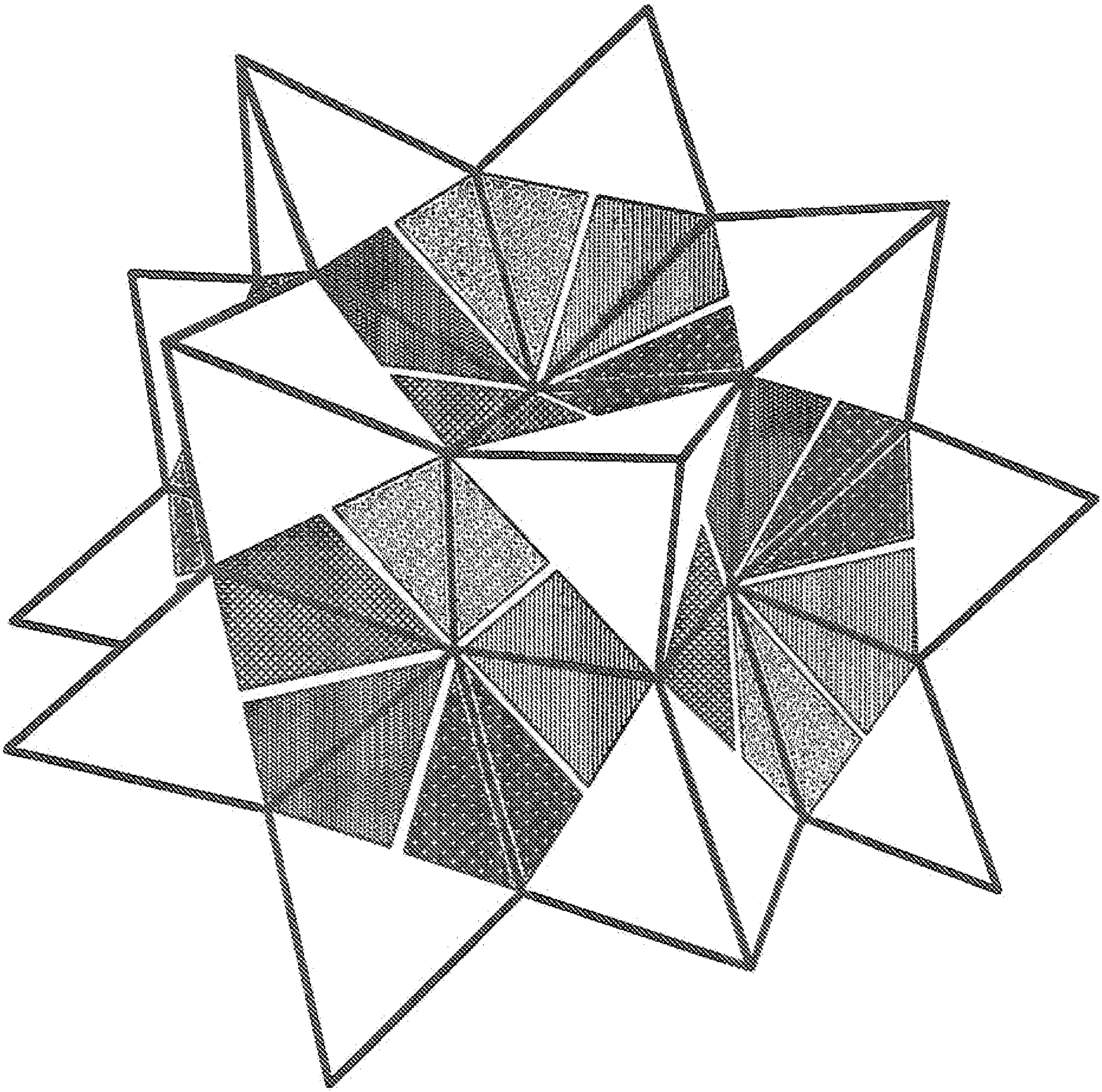

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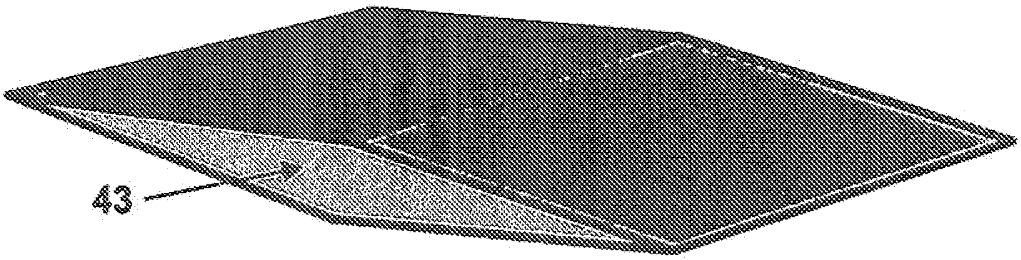

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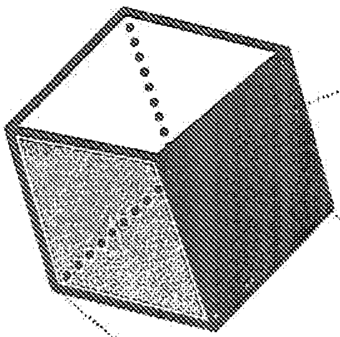

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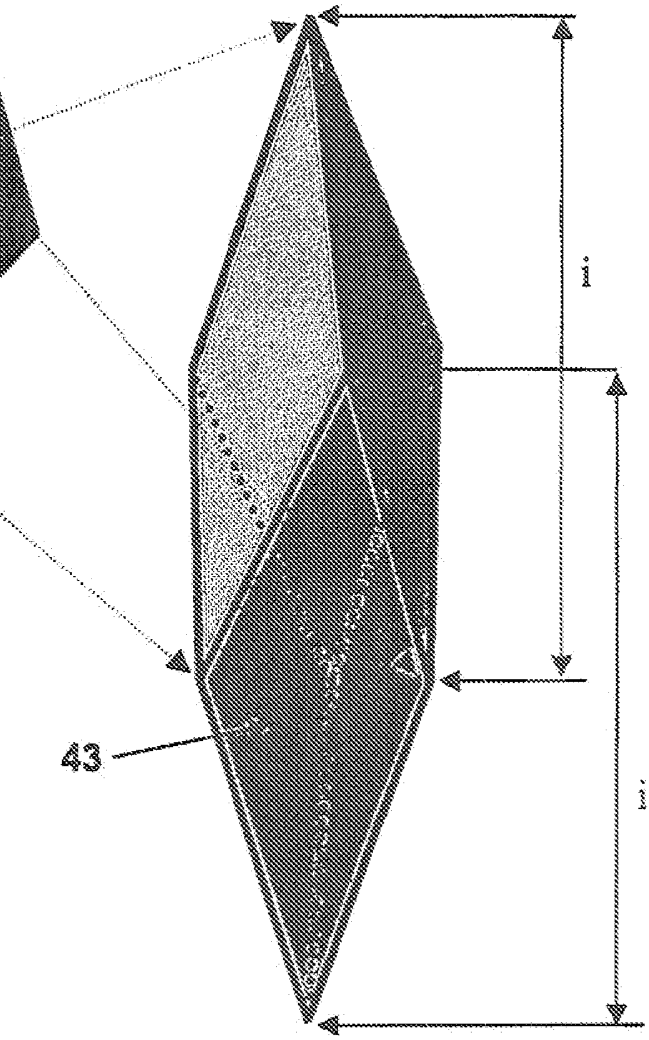
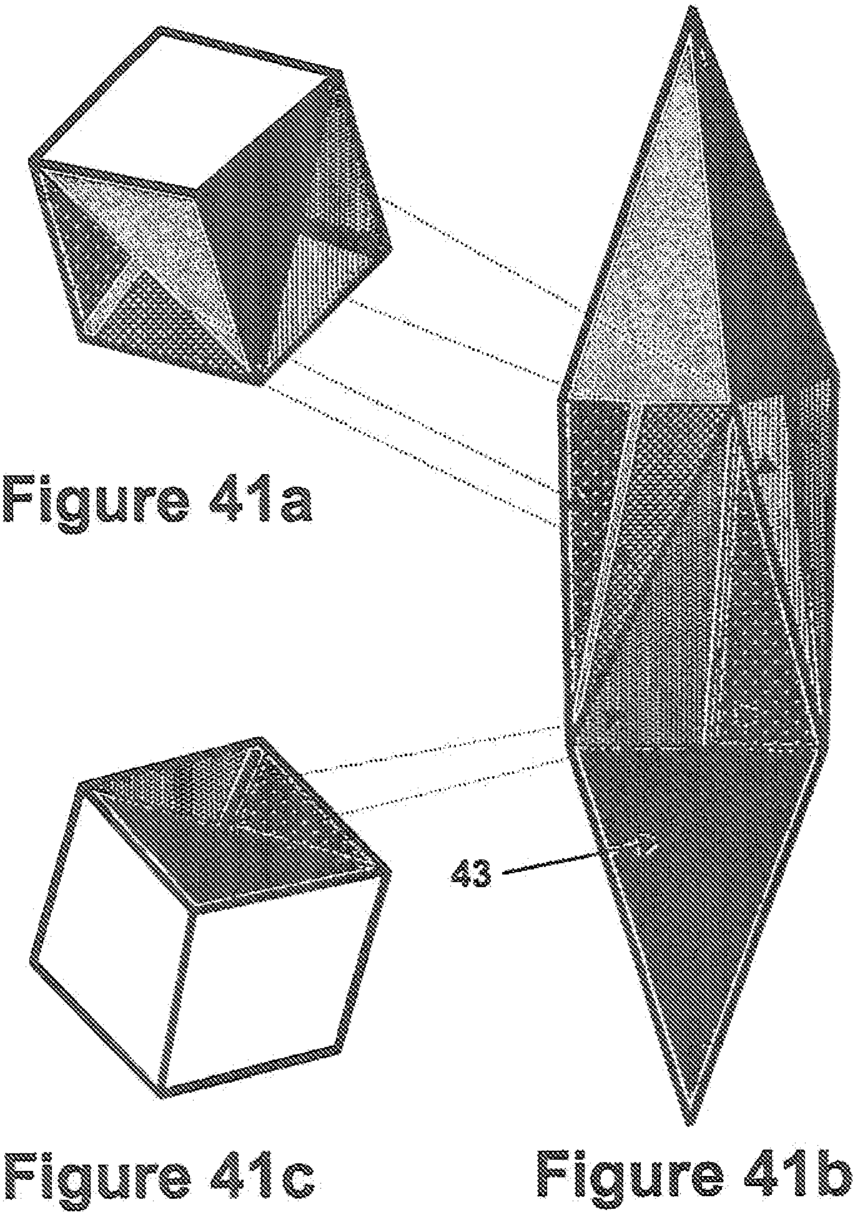


Figure 40c

Figure 40



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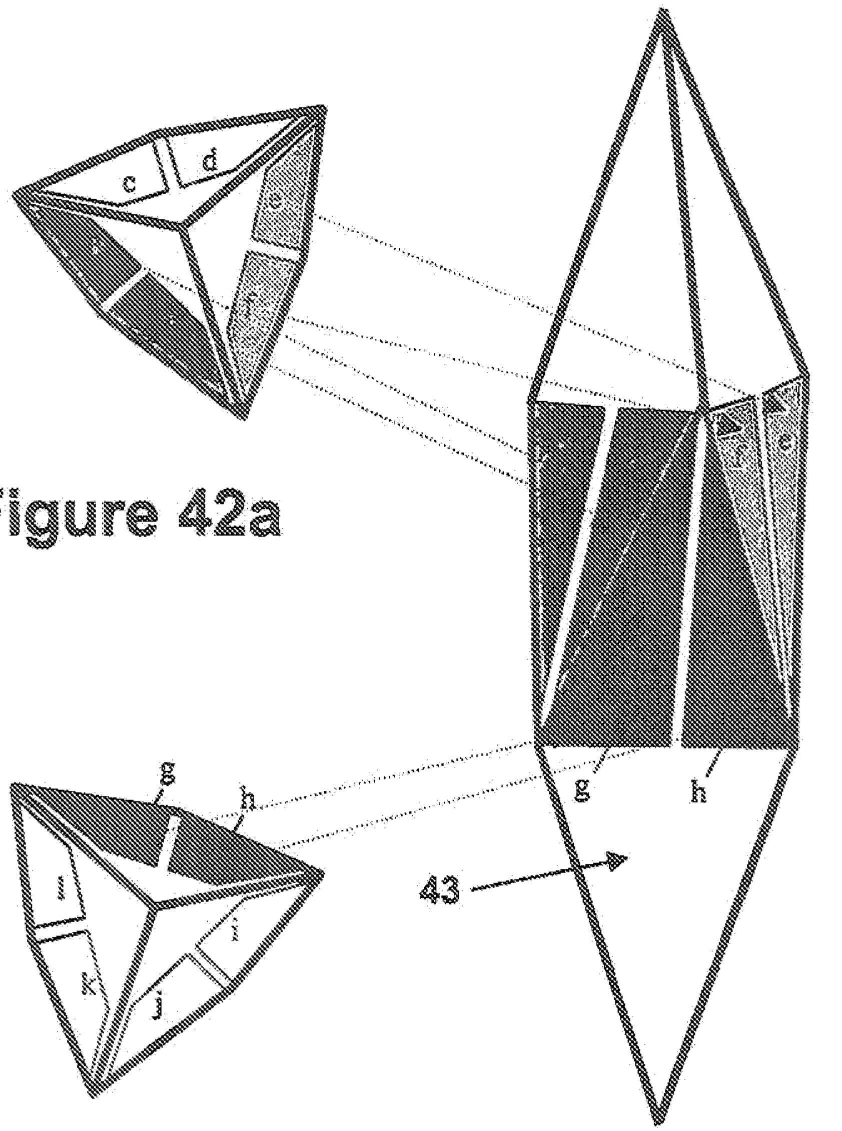
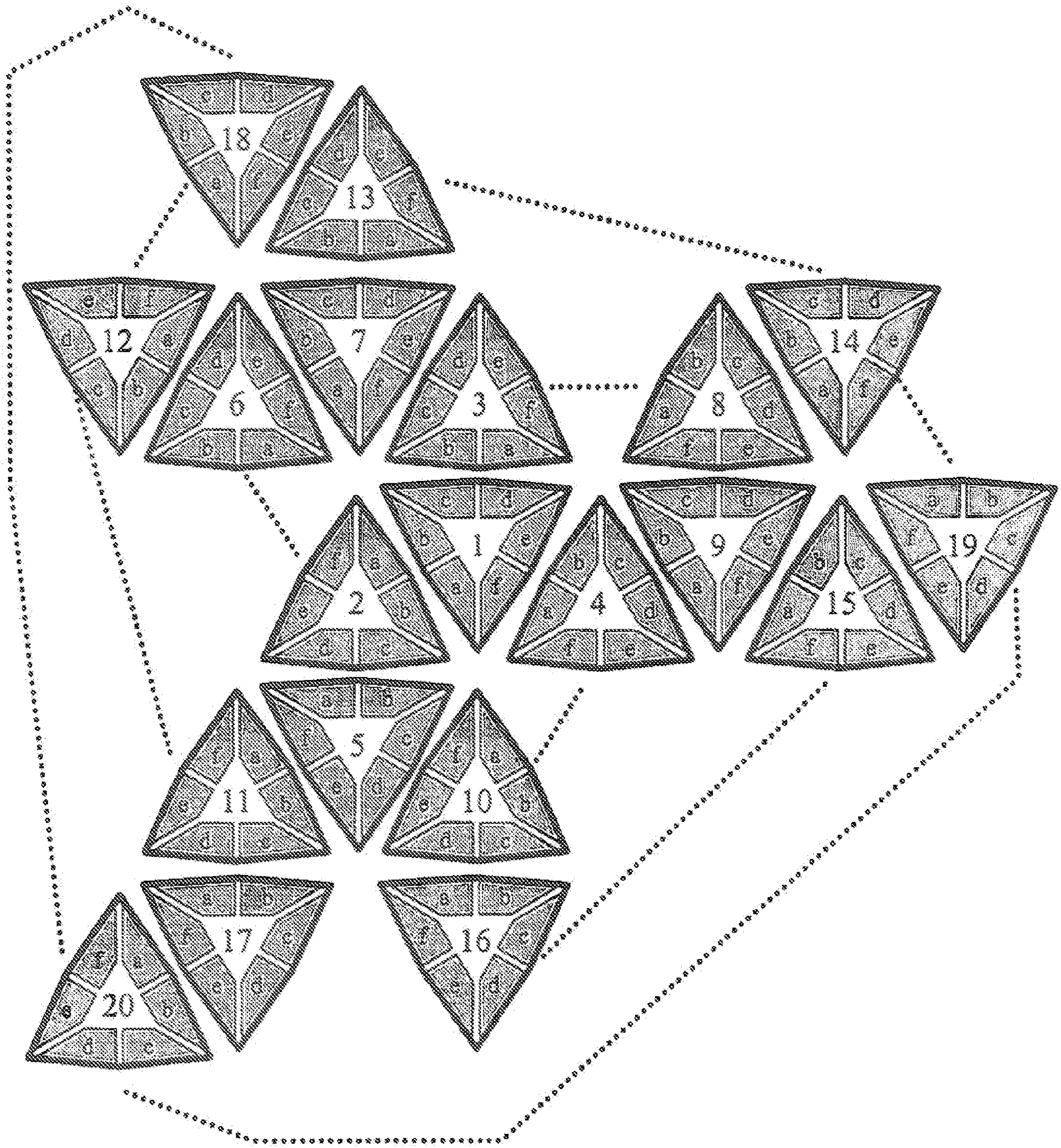


Figure 42a

Figure 42c

Figure 42b

Figure 42



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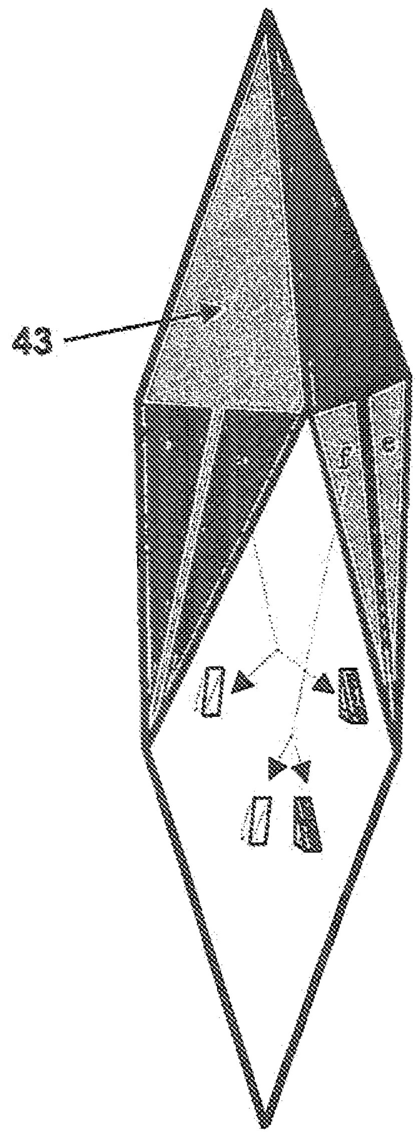

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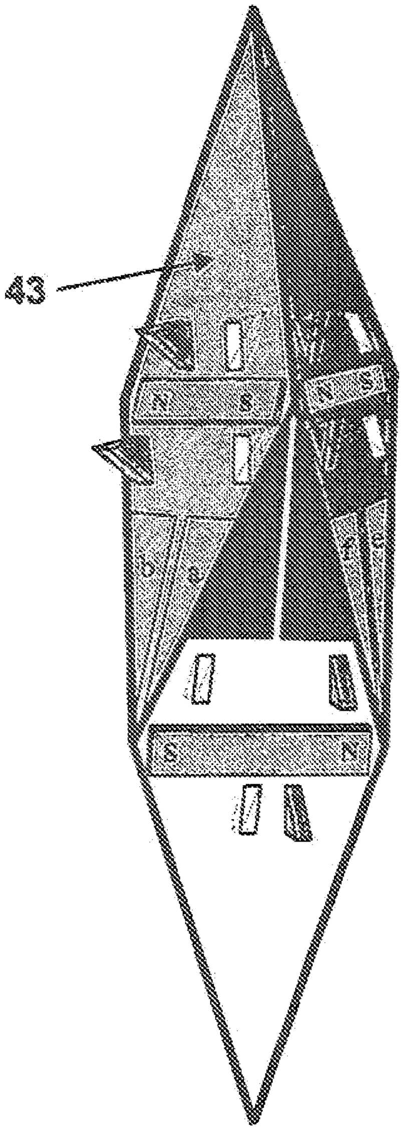

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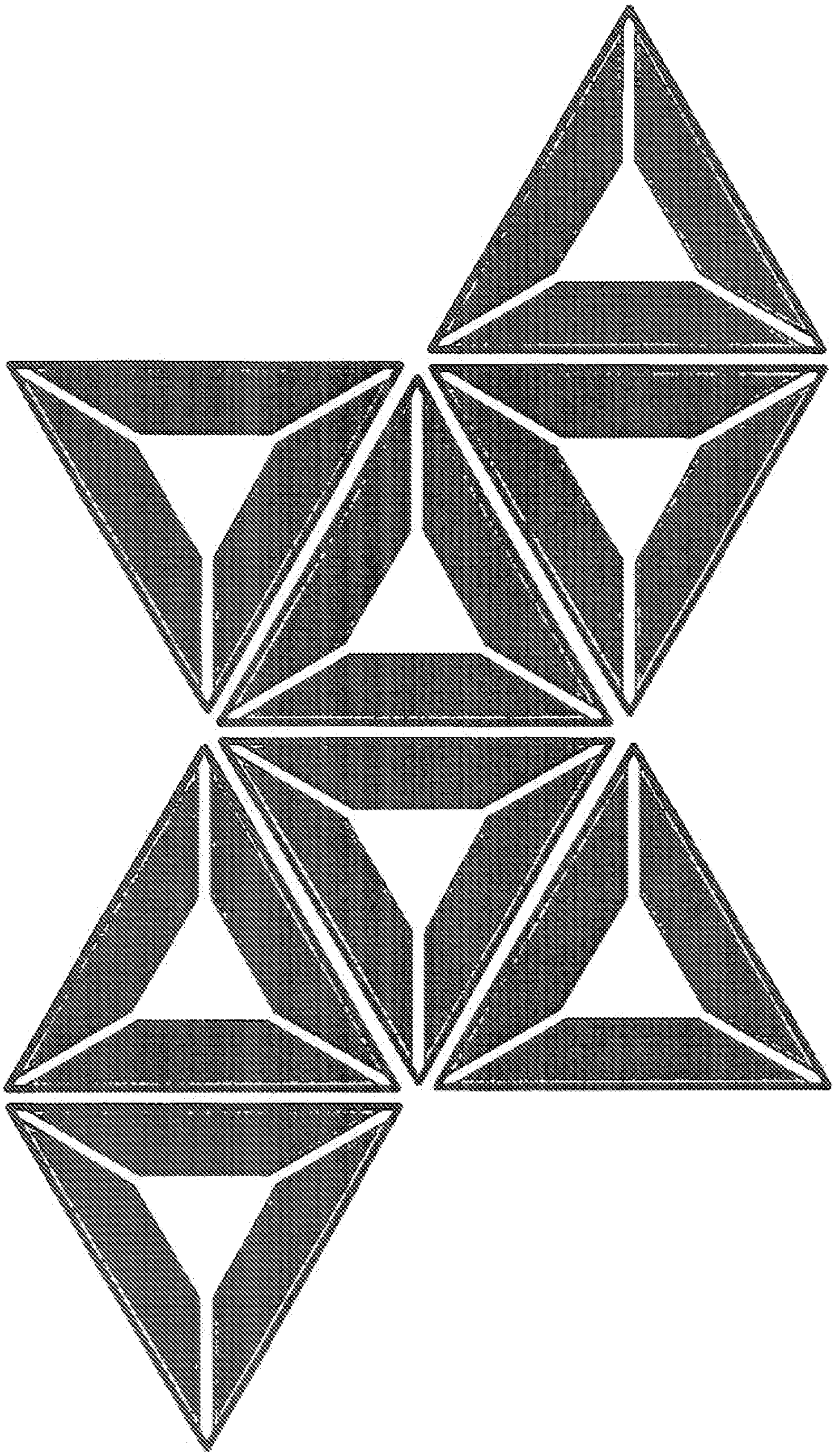

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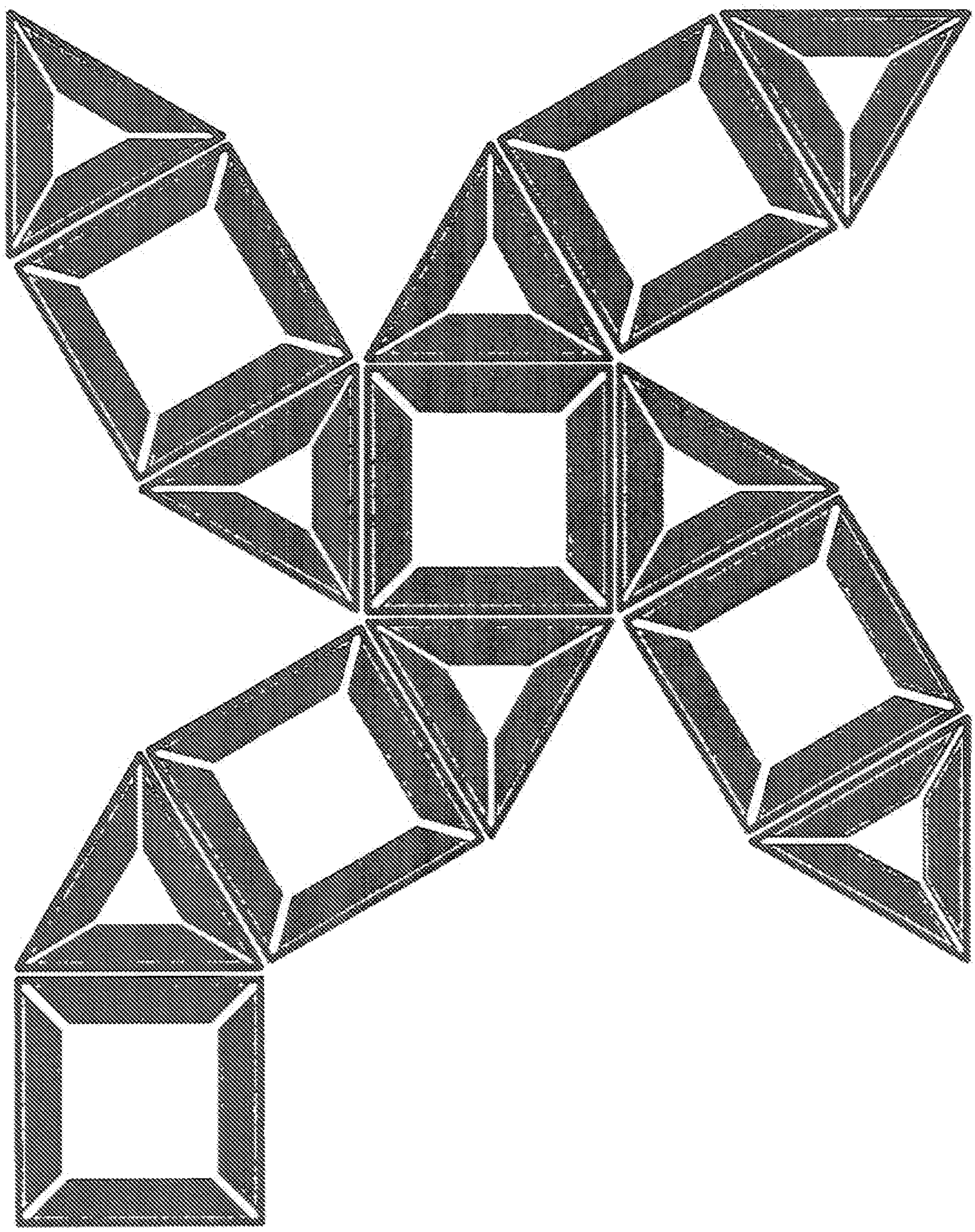

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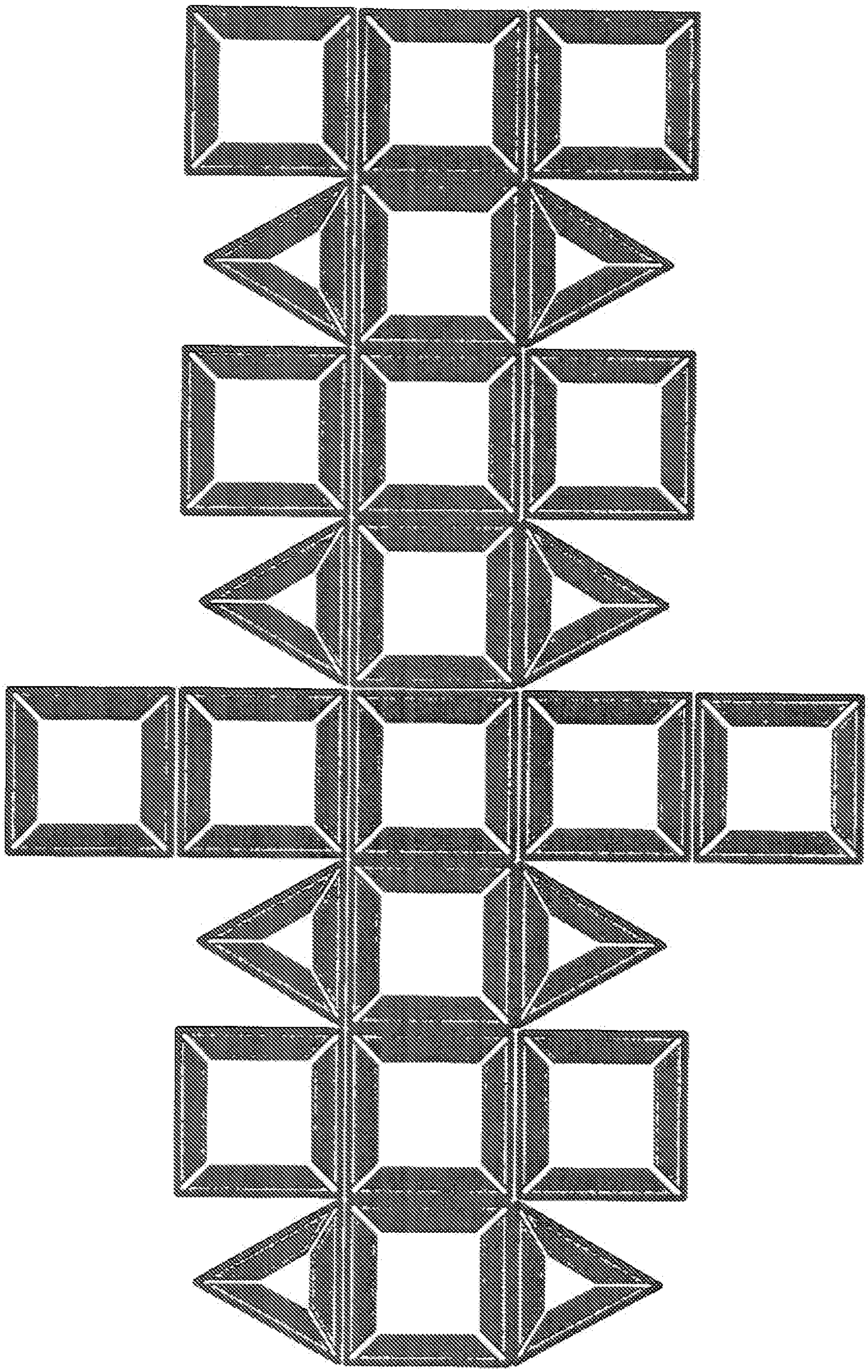

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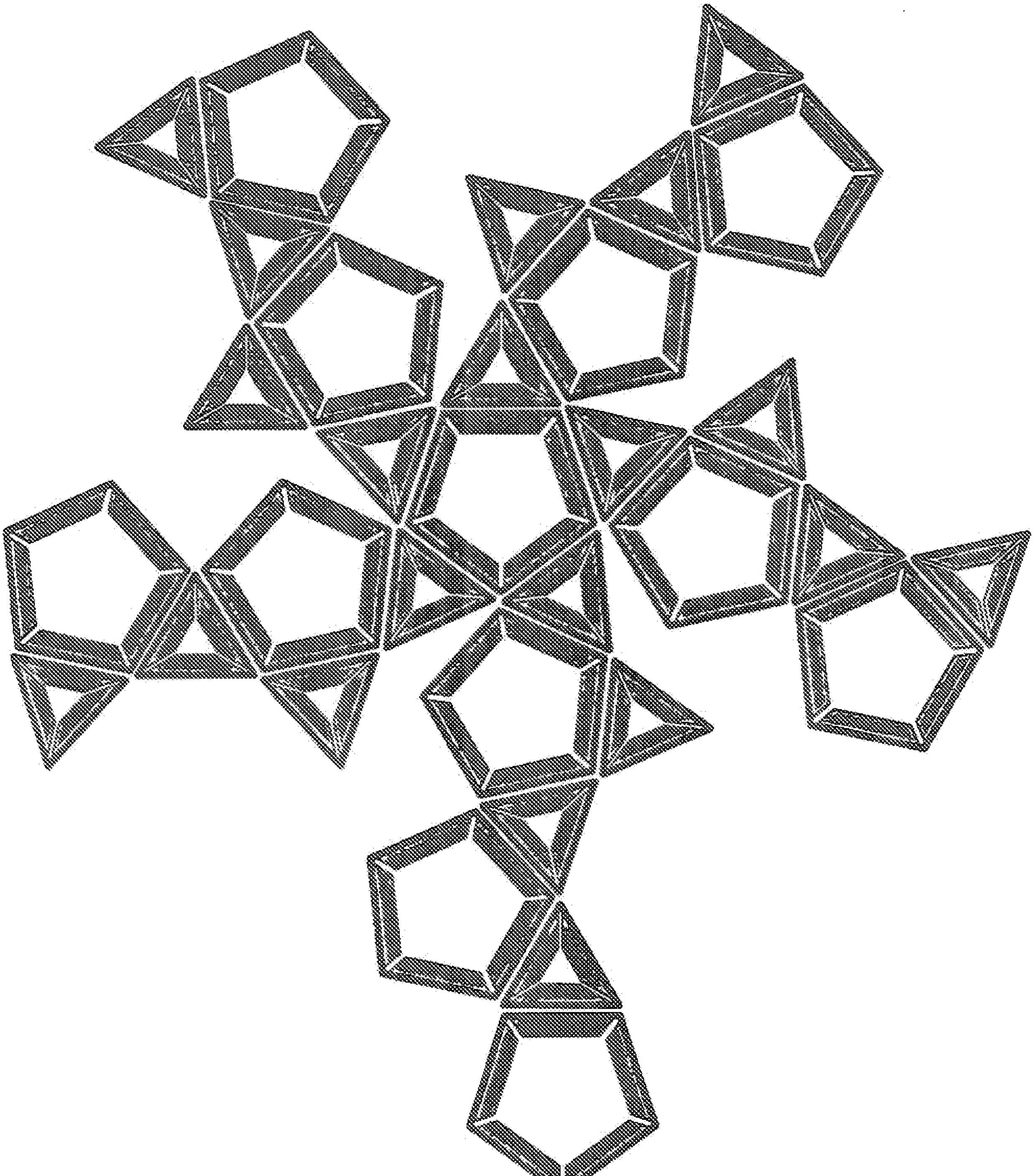

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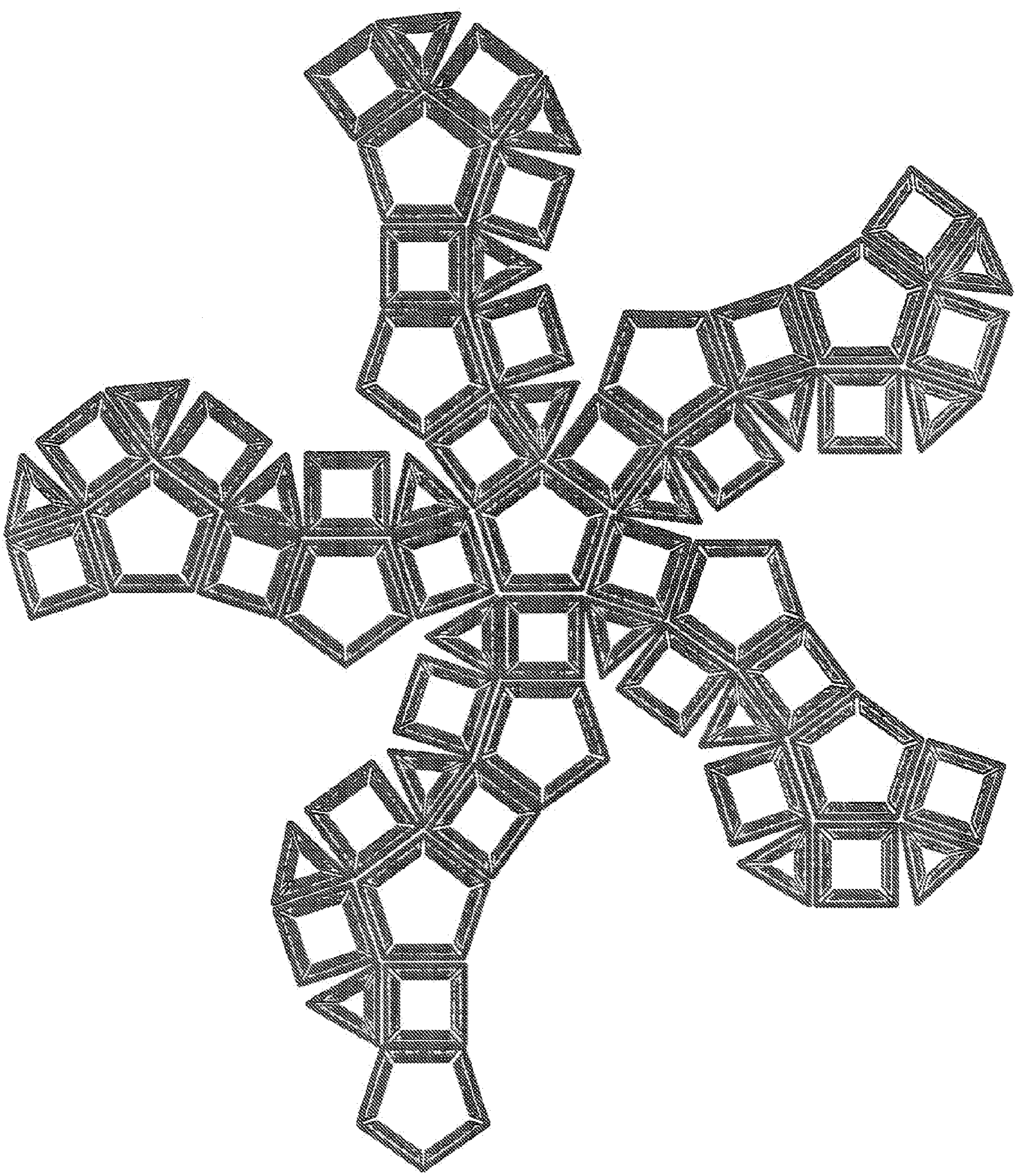

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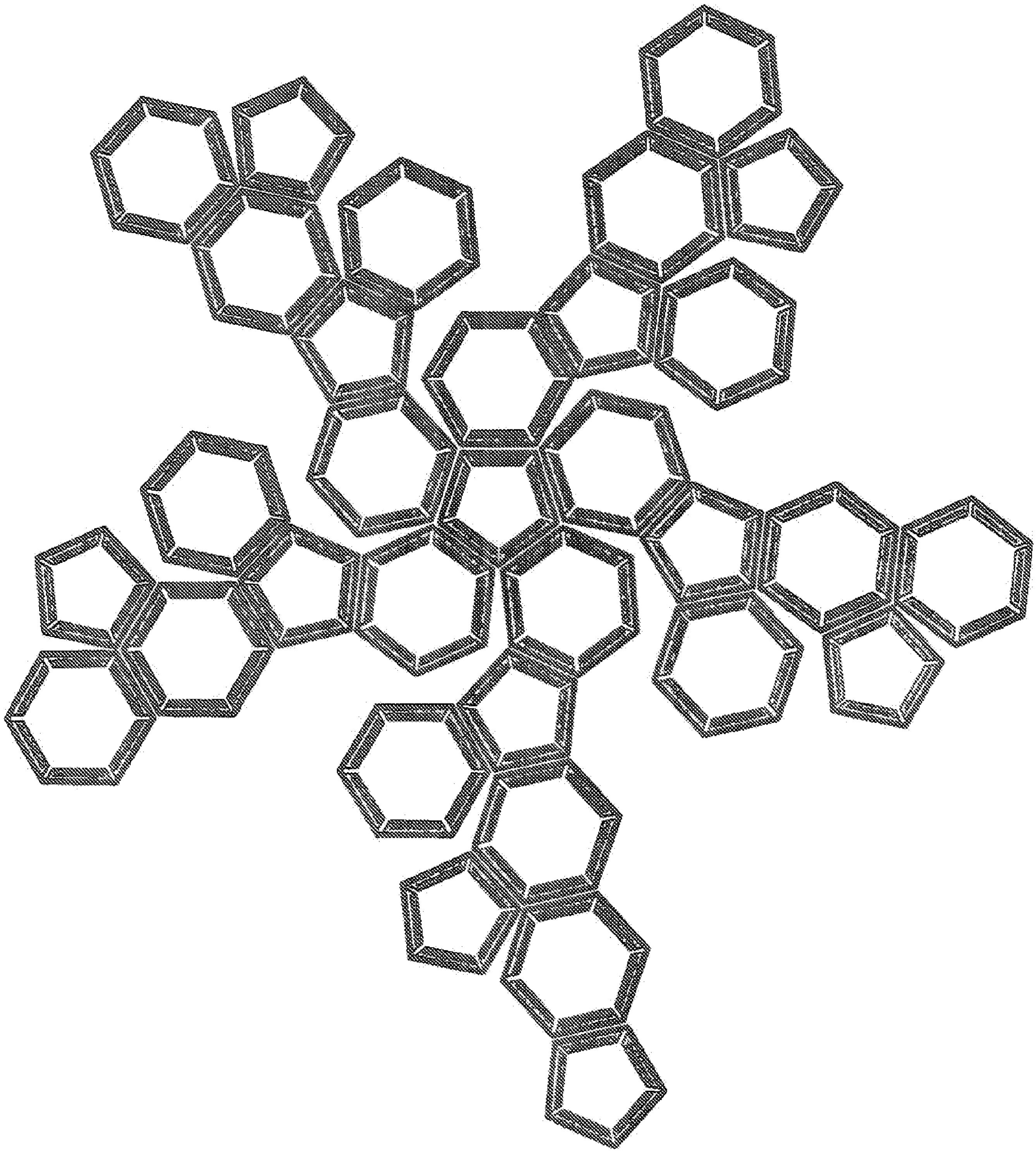

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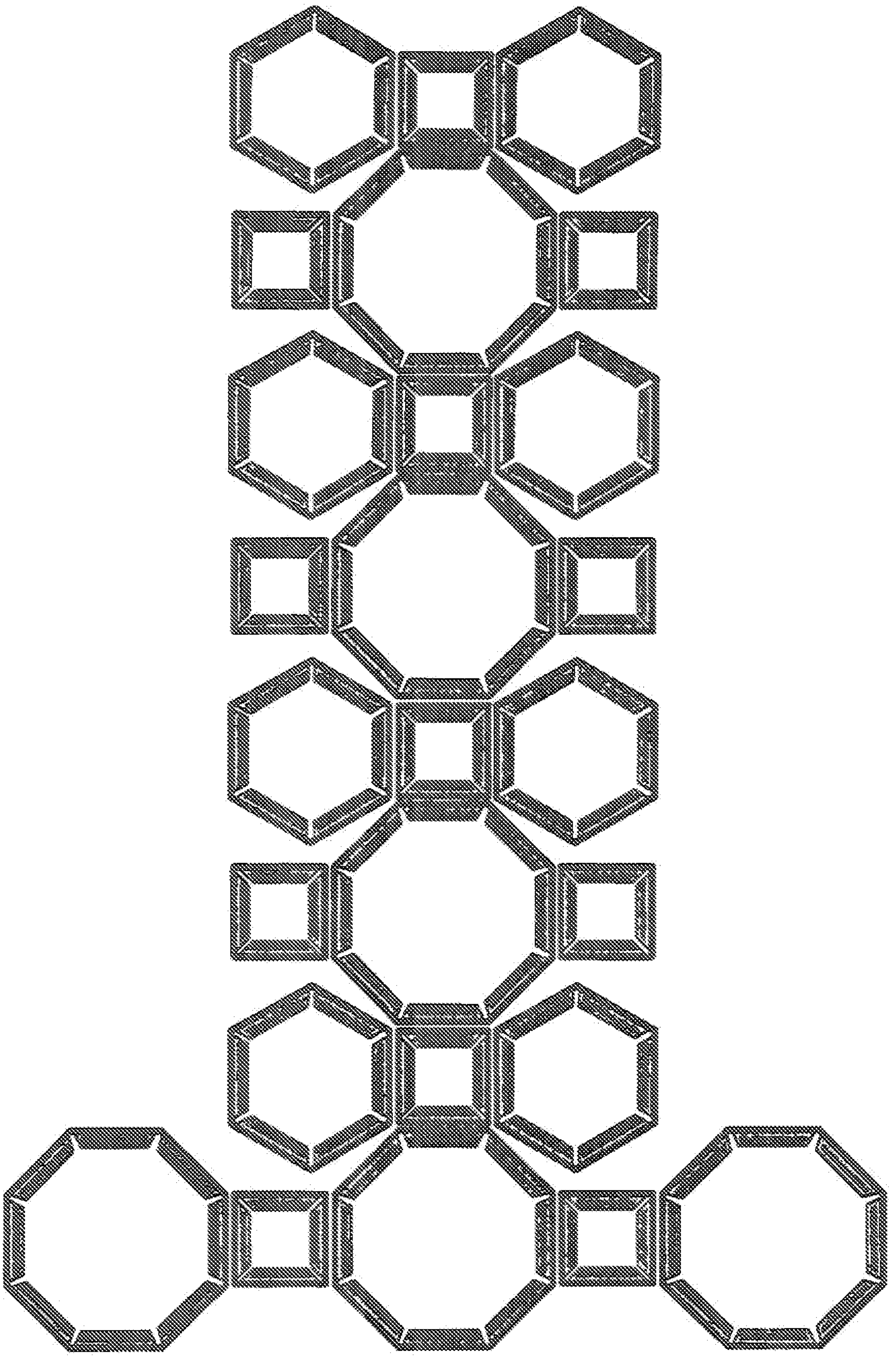

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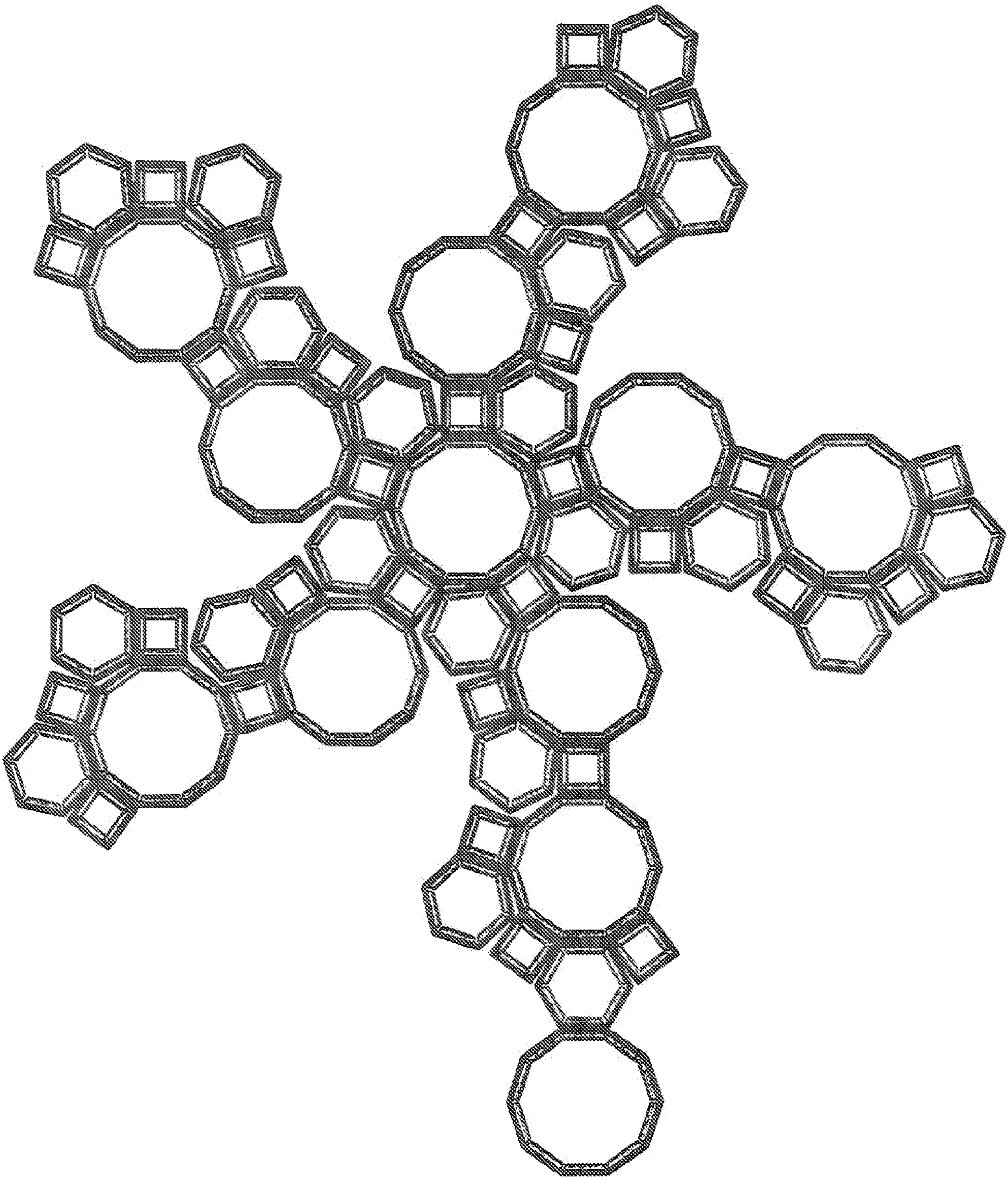

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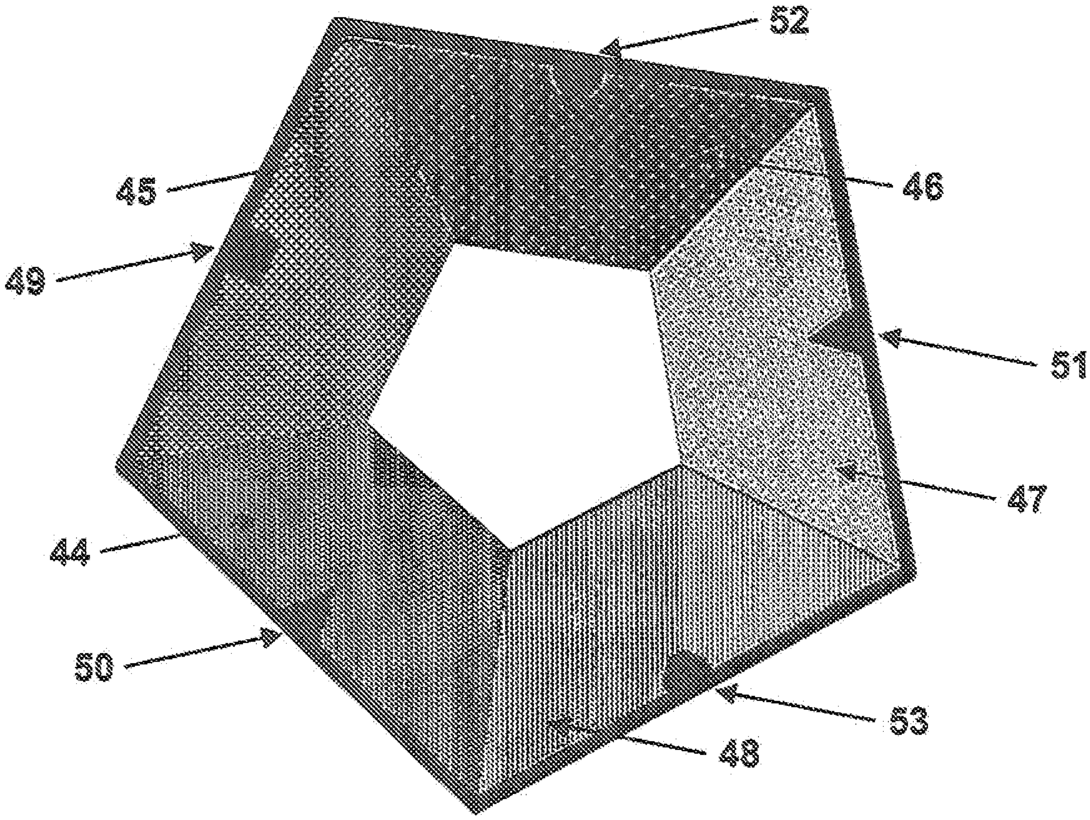

Figure 54