PART I: VISUAL ARTS & MATHEMATICS

AGE RANGE: 13-15 and 16-18

TOOL 7: A SYNCHRONOUS EXHIBITION OF ART-MATH MASTERPIECES

C.I.P. Citizens In Power

TheArtOf Maths

Co-funded by the Erasmus+ Programme of the European Union

Educator's Guide

Title: A synchronous exhibition of Art-Math masterpieces

Age Range: 13-15 and 16-18 years old (preferably for 16-18 years old)

Duration: 2 hours

Mathematical Concepts: Euclidean/Non-Euclidean Geometry, stereometrics, hyperbolic geometry, Mobius Strip, fractals, four-dimensional geometry, tesseract

Artistic Concepts: sculptures, computer-aided design, metal printing technology

General Objectives: Students will have the opportunity to investigate how math have influenced visual arts in the recent years, whilst also comprehending ways in which mathematics are able to define the properties of space, as those could be depicted through visual arts

Instructions and Methodologies: It is preferable to follow the structure of this tool as it is gradually given to the reader; first, the work of 8 distinguished visual artists is being displayed, by indicating the ways in which their masterpieces reflect to real math concepts and theories. Subsequently, within "The Math behind" section, all the basic math concepts demonstrated within the exhibition are being defined. The tool ends up with a task which requires from the student to match previously analyzed math concepts with relevant images, thus acquiring a better understanding on different math geometries, also applicable in visual arts.

Resources: This tool provides an overview of each artist's work, enriched with recent pictures taken from artists' exhibitions and personal collections. Additionally, students are invited to go deeper and discover more about the artists, through recommended links and you-tube videos.

Tips for the educator: The educator could ask students to form small groups; each of them could emphasize on one of the artists presented within the synchronous exhibition of the tool. As a last step, the educator could ask the groups to present their findings in order to detect commonalities between the artists and the way of depicting math concepts.

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Desirable Outcomes and Competences: Students will have acquired knowledge related to modern "mathematical" artists, thus comprehending in depth the real borders of visual arts and sciences.

Debriefing and Evaluation Questions: As part of reflection and/or formative assessment (=in order to improve the tool for the next time according to the students' background, interest, exact age, country's culture, students' prior knowledge etc.) the educator can use these cards sometimes called EXIT CARDS either by a hard copy he/she has made from before or simply by posing these statements on board and the students write the answers on a paper which they will leave preferably anonymously while exiting the room. The specific formative strategy is called 3,2,1. For more strategies you can visit:

https://www.bhamcityschools.org/cms/lib/AL01001646/Centricity/Domain/131/70%20Formative%20Assessments.pdf

3-2-1	
Write 3 things you liked about this activity	**1.** **2.** **3.**
Write 2 things you have learned	**1.** **2.**
Write 1 aspect for improvement	**1.**

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Introduction

Within this work, you will get in touch with the artworks of 8 well-reputed artists whose work reflects on math theories and concepts, mostly related to different types of geometry, namely Euclidean geometry and its axioms and non-Euclidean geometry (through hyperbolic space). Additionally, you will acquire a first (basic) understanding of the differences in the formation of a three-dimensional (3-D) and a four-dimensional space (4-D). Last, you will start conceiving the influence of new media and technologies in the creation of artistic masterpieces; a good example of such influence is the so called "computer art/graphics".

Bathsheba Grossman; the sculptor who depicts mathematical oddities

Bathsheba Grossman is an American artist who was born in 1966. She creates sculptures through the use of computer-aided design and three-dimensional modelling, with metal printing technology. The main materials for her sculptures are bronze or stainless steel. Her bronze sculptures have drawn to a large extent from mathematics, while they usually depict three dimensional patterns or mathematical oddities. Her work is heavily influenced by natural sciences, such as biology, astronomy and physics.

Her website contains a special section, focused on artworks which attempt to depict concepts deriving from natural world and sciences (e.g. DNA, glass brain, insulin, Caffeine, DNA keychain and Polymerase, Geodynamo (Earth's magnetic field), Atomic Orbitals (where's the electron?), etc.

Use this link https://www.bathsheba.com/crystal/index.html#physics to come in touch with Grossman's artworks, through her official website.

Her artworks related to Math depict geometrical objects; The Klein Bottle Opener, Gyroid, etc. They could be found and explained in the following link: https://www.bathsheba.com/math/

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Picture: Mathematical Sculpture used as a lamp, Bathsheba Grossman, 2007 (Retrieved from: https://en.wikipedia.org/wiki/Bathsheba_Grossman)

- **Watch the following videos in order to get acquainted with Grossman's work:**

https://www.egconf.com/videos/bathsheba-grossman-sculptor-ubernerd-eg7

https://www.youtube.com/watch?v=LKysk-M1Y94

https://www.youtube.com/watch?v=FMSuwPNvzPw

Hartmut Skerbisch; the man who conceptualized sculpture as an exclusive spatial language

He was born in 1945 in Ramsau am Dachstein, even though he worked in Kalsdorf bei Ilz, East Styria, Austria. Although he studied architecture, he had worked as a video artist, sculptor and photographer since 1969. All his artworks principally examined spatial concepts, while the latter had been approached and artistically communicated as a distinctive language. Skerbisch's sculptures had been influenced by the rise of electronic media.

He was mostly impacted by political and scientific concepts rather than artistic ones; hence, some of his sculptures were created in consistency with geometric axioms, such as the ones presented in the pictures, which were mainly based on the theory of

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fractals. Fractal is a curve or geometrical figure, each part of which has the same statistical character as the whole. They are useful in modelling structures (such as snowflakes) in which similar patterns recur at progressively smaller scales, and in describing partly random or chaotic phenomena such as crystal growth and galaxy formation.

He had been exhibiting his artworks continually since 1975, while in 1993 he received the 'Fine Art Award' by the City of Graz in Austria, where he died in 2009.

- **Use this link in order to come in touch with the artist's work, through his official website.**

  http://hartmutskerbisch.org/about/hartmut-skerbisch/?lang=en

Picture: Retrieved from https://commons.wikimedia.org/wiki/File:Hartmut_Skerbisch.jpg

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Pictures: Fractal sculpture: 3D Fractal by Hartmut Skerbisch, 2003 (Retrieved from: http://hartmutskerbisch.org/work/3d-fraktal-03hdd-2003/?lang=en)

Desmond Paul Henry; the pioneer in Computer Art

Desmond Paul Henry (1921-2004) is one of the first British pioneers in Computer Art/Graphics, since he had begun working in this field during the 1960's; this was a decade in which he initially developed "three mechanical drawing machines based around the components of analogue bomb-sight computers". Henry's life-long passion for all things mechanical motivated him to purchase an army surplus analogue bombsight computer in the early 1950s. For years he would gaze fascinated at the 'peerless parabolas' (Henry) of its inner working parts while it was in motion. Later, in the early sixties, he took the decision to record these mechanical motions on paper and so was born the first of a series of three drawing machines based around the components of the bombsight computer itself (source: http://www.desmondhenry.com/about/).

In the1960s Henry constructed drawing machines had been able to develop fractal patterns, whilst he kept developing this idea up to 2000, when his patterns exemplified different commonalities with organic forms or with "natural form mathematics", as he used to call them.

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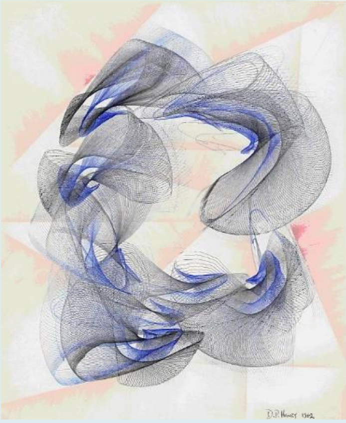

Pictures: Computer Art; Desmond Paul Henry 1962-1964 (retrieved from the artist's official website gallery http://www.desmondhenry.com/gallery/)

- **If you want to learn more about Henry's work, refer to his official website by using this link:**

  http://www.desmondhenry.com

- **You can also watch the following video about Desmond Paul Henry's life and work:**

  https://www.youtube.com/watch?v=eQIEGkME0cA

Hamid Naderi Yeganeh; the artist of mathematical formulas

Hamid Naderi Yeganeh was born on July 26, 1990 in Iran and is a mathematical artist. He became famous for using mathematical formulas to design drawings of real-life objects, intricate illustrations, animations, fractals and tessellations. The American

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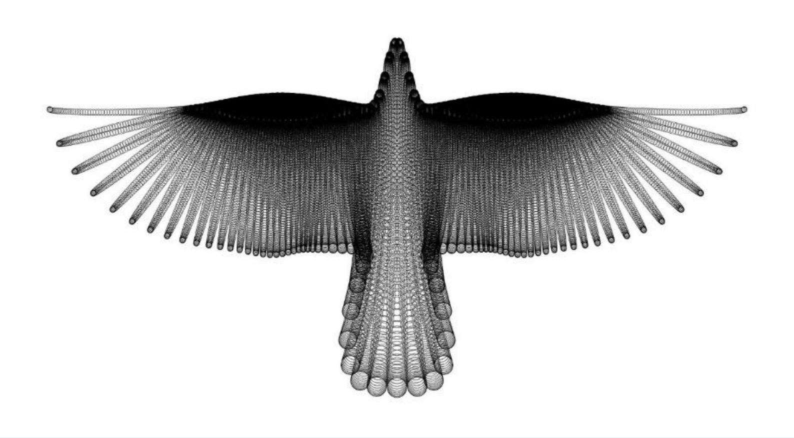
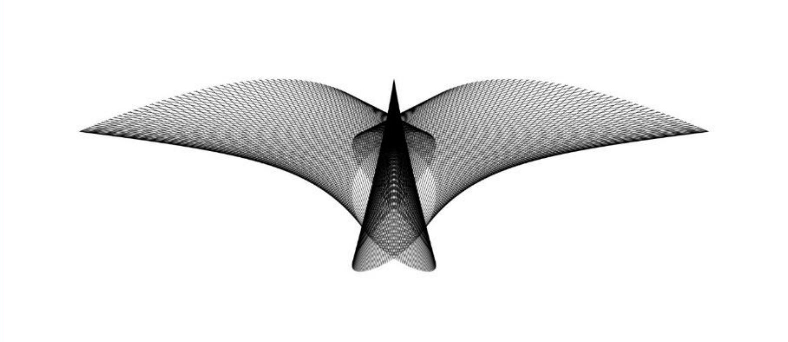
Mathematical Monthly used his artwork "9,000 Ellipses" as the background cover image of the November 2017 issue.

Naderi Yeganeh has invented two methods to design real-life objects with mathematical formulas. In the first method, he constructs tens of thousands of computer-generated mathematical figures to come across some interesting shapes by accident. For example, by using this method, he discovered some shapes that resemble birds, fishes and sailing boats. In the second method, he sketches out a real-life object with a step-by-step technique. In each step, he attempts to discover which mathematical formulas will develop the drawing. For instance, by using this method, he drew birds in flight, butterflies, human faces and plants using trigonometric functions. He has constructed some fractals and tessellations inspired by the continents, an example of which is the 2015 artwork of fractal Africa being described as an Africa-like octagon and its lateral inversion.





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Pictures: Birds in Figure (Retrieved from https://en.wikipedia.org/wiki/Hamid_Naderi_Yeganeh); Hamid Naderi Yeganeh, 2016, constructed with a family of mathematical curves (Retrieved from: https://es.wikipedia.org/wiki/Archivo:A_Bird_in_Flight_by_Hamid_Naderi_Yeganeh.jpg)

Tony Robbin

Tony Robbin (born in 1943, Washington, DC) is a U.S.-born artist who emphasizes on painting, sculpture, as well as on computer visualizations as a means of creating his artworks. Robbin belongs to the "Pattern and Decoration" art movement, whilst he can be regarded as a pioneer when it comes to computer visualization of four-dimensional geometry and quasicrystal space. In particular, Robbin has developed rotation programs, fit for four-dimensional structures, capable of providing an intuitive sense of how four-dimensional and quasicrystal spaces operate.

Since 1974, Robbin has presented over 25 personal exhibitions in painting and sculpture, whilst being included in more than 100 collective exhibitions all over the world. He is also the author of four books: "Fourfield: Computers, Art, & the 4th Dimension"(1992); "Engineering A New Architecture"(1996); "Shadows of Reality", (2006); and "Mood Swings A Painters Life" (2011).

As written in Robbin's official website: "Robbin's closeness to the mathematics community led him to Quasicrystal geometry, a derivative of four-dimensional geometry with truly remarkable visual properties. He decided that architecture was the preferred art form for this new idea. He holds the patent on the application of Quasicrystal geometry to architecture and has lectured and written so widely on the idea that it is now studied in architecture schools, primarily in Europe" (Online Source: http://tonyrobbin.net/work.htm).

- **For more info on Robbin's work, you can study further his official website:**

  http://tonyrobbin.net/

- **Films/Videos that present Robbin's lectures, speeches, etc. can also be found within his official website:**

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http://tonyrobbin.net/flm.html

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Pictures: Tony Robin's artworks which have been retrieved from his official website

Charles O. Perry

"The breadth of expression possible with mathematics as a discipline is almost endless. The real reason that I deal with mathematics is that this is what excites me. Just as it sets my brain off to hear Bach, so the exquisite natural laws of form strike a chord in me. Figurative sculpture is often amazingly beautiful, but I'm not built to do that."

Charles O. Perry (extract retrieved from http://symmetry-us.com/Journals/perry/p16.htm)

Charles O. Perry (1929-2011) was an U.S.-born sculptor, architect and designer, renowned for his large-scale and mathematically inspired sculptures, which can be found in public sculpture gardens and squares in the United States, Australia, Saudi Arabia, Singapore and Japan, whilst some of them constitute parts of private collections across the globe. One of his best-known mathematical sculptures is 'Continuum', which had been based on the idea of Möbius strip and has been positioned at the entrance of the Smithsonian's National Air and Space Museum in Washington.

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Picture: 'Continuum', 1976, has been positioned at the entrance of the Smithsonian's National Air and Space Museum in Washington (Picture retrieved from: https://www.nytimes.com/2011/02/11/arts/design/11perry.html)

As written in the artist's official website, Perry's "intuitive investigation of nature variables, provides the springboard for many of his concepts. Believing that sculpture must stand on its own merit without need of explanation, Perry's work has an elegance of form that masks the mathematical and scientific complexity of its genesis. He has lectured on mathematics and art in conferences throughout the world" (Online source: http://www.charlesperry.com/).

In his article 'Morphology to Sculpture', Perry analysed some crossover points between mathematics, sculpture and architecture. As he described, "[m]orphology is a fascinating science. This is the mathematics of all our material world, the architecture and sculpture of nature (and us). My work has always started from this direction. Three of the recent pieces that I have been working on intertwine mathematics, sculpture and architecture. This was an unconscious effort, for me it's just the way the sculpture "wants to be". The perceptible order of my work is always trying to reach back into our brain and whisper "what does it mean?"" (Online source: http://nyjm.albany.edu/am/1997/Perry.pdf)

- **For more information on Charles O. Perry's work, you can visit his official website**

http://www.charlesperry.com/

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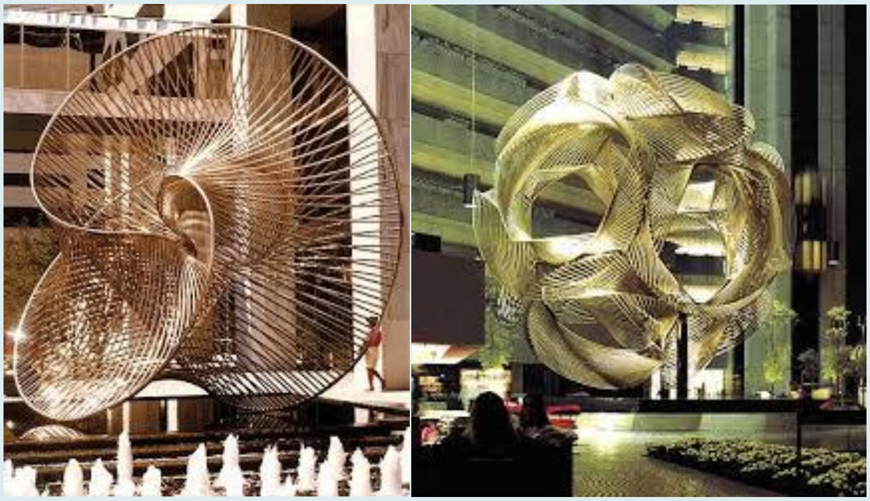
- You can also watch the following videos:

https://www.youtube.com/watch?v=zgbx83l9kNg

https://www.youtube.com/watch?v=wt4RlhBkjEk&list=PLYyL528E9libFlc4EoX_ik_7lFcUNohX3&index=2



Picture: Charly O. Perry (In the left-hand side: Solstice; In the right-hand side: Equinox)

Picture: Charles O. Perry, Solar Cantata

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Picture: Left-hand side: Charles O. Perry, Infinity; Right-hand side: Charles O. Perry, Star Mobius

Daina Taimina

The Latvian mathematician Daina Taimina (1954) works as an Adjunct Associate Professor at Cornell University. Taimina has become a notable mathematical artist as a result of her focus on the construction of hyperbolic handicrafts. By taking up crafts from her early childhood, when she learnt how to knit and crochet, Taimina has been transforming crocheted surfaces into symmetric hyperbolic planes with success, which not only consist laudable aesthetic masterpieces, but can also be employed as a pedagogical toolkit, adequate for helping students to intuitively acquire a comprehension of non-Euclidean geometry, thus assisting them in tackling their math phobia. In particular, Taimina along with her husband, Dr David Henderson, who is a mathematics professor at Cornell, have presented the pedagogical applicability of such innovation, whilst they have also utilized crocheted mathematical models as examples within their geometry books, such as their textbook entitled as: "Experiencing Geometry: Euclidean and non-Euclidean with history".

Through Taimina's presentation about hyperbolic space and its correlation to nature, which is directed towards the general public, but also to artists and movie producers, she managed to popularize mathematics, and especially the advanced concept of hyperbolic geometry.

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In 2005, Taimina organized an exhibition entitled as "Not The Knitting You Know", which took place at the art gallery "Eleven Eleven Sculpture Space" in Washington, D.C. She has also exhibited her work in other galleries in US, as well as in a number of European countries, such as in Latvia, Belgium, UK, Ireland and Italy. Her artwork has been part of important exhibitions and collections of distinguished institutions, including universities, like the American Mathematical Model Collection of the Smithsonian Museum, the National Design Museum and the Institute Henri Poincare.

- **For more information, watch Daina Taimina's speech "Crocheting Hyperbolic Planes" for TEDx, by using the link**

https://www.youtube.com/watch?v=w1TBZhd-sN0

- **In addition, watch Taimina's lecture of 16/05/17 "Study mathematics and … become an artist" in the following links:**

https://crochetcoralreef.org/contributors/daina_taimina.php
http://pi.math.cornell.edu/~dtaimina/

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Pictures: Retrieved from the artist's official website

Hiroshi Sugimoto

Hiroshi Sugimoto is a Japanese photographer and architect, who was born in Tokyo, Japan, in 1948. Nonetheless, he has been widely renowned for his painter-like photographic style. According to bibliography, Sugimoto draw inspiration by Marcel Duchamp who used to focus on the mechanics of the space, as well as by the Man Ray who photographed mathematical models in the 19th century.

Through his London exhibition "Conceptual Forms", Sugimoto presented a series of black and white photographs illustrating both mathematical models and mechanical machine tools, remarkable for their large scale. This exhibition was inspired by mathematics and modernist sculpture. Plaster stereometric models, portrayed within Sugimoto's work, had been created in the 19th century, so as to be used as pedagogical tools that provide to the students an improved understanding of trigonometric formulas. On the other side, the depicted (photographed) mechanical tools had been constructed with the aim to display some of the most fundamental movements, characteristic of synchronous machineries.

As it's being noted on the Gagosian Gallery webpage, Sugimoto started working on this project as a response to "The Bride Stripped Bare by Her Bachelors, Even (The Large Glass)" by Marcel Duchamp. "In Sugimoto's photographs, the fluid curvilinear forms of the mathematical models (those objects reminiscent of the "Bride") and the rigid, sharply delineated forms of the mechanical models (those mechanics

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associated with the "Bachelors") become abstract sculpture, blurring the line between science and knowledge, and their relationship to art" (online source: https://gagosian.com/exhibitions/2005/hiroshi-sugimoto-conceptual-forms/).

- **If you want to learn more on Sugimoto's mathematical work, watch the following video, related to his conceptual forms and mathematical models, through which the notion of infinity is being discussed in brief.**

https://www.youtube.com/watch?v=ax_i65W8Fhk

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Picture: Hiroshi Sugimoto; Conceptual Forms

The Math Behind the art-math exhibition

Get acquainted with the mathematical concepts presented within the synchronous exhibition

- **FOUR-DIMENSIONAL GEOMETRY**

A four-dimensional space or 4D space is a mathematical extension of the concept of three-dimensional or 3D space. Three-dimensional space is the simplest possible abstraction of the observation that one only needs three numbers, called dimensions, to describe the sizes or locations of objects in the everyday world. For example, the volume of a rectangular box is found by measuring its length, width, and height (often labeled x, y, and z).

4D, meaning the 4 common dimensions, is an important idea in physics referring to three-dimensional space (3D), which adds the dimension of time to the other three dimensions of length, width, and depth. In geometry, the fourth dimension is related to the other three dimensions by imagining another direction through space; just as the dimension of depth can be added to a square to create a cube, the fourth dimension can be added to a cube to create a tesseract (four dimensional object)

- **Use the following links to learn more about four dimensional spaces:**

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https://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/four_dimensions/index.html

https://www.youtube.com/watch?v=iGO12Z5Lw8s

- **FRACTALS**

A curve or geometrical figure, each part of which has the same statistical character as the whole. They are useful in modelling structures (such as snowflakes) in which similar patterns recur at progressively smaller scales, and in describing partly random or chaotic phenomena such as crystal growth and galaxy formation.
Use the following links to discover and play with fractals:

FRACTAL FOUNDATION: https://fractalfoundation.org/about-us/

FRACTAL IN NATURE: https://www.youtube.com/watch?v=GKYG__-HATI

- **COMPUTER ART/GRAPHICS**

Computer art typically refers to any form of graphic art or digital imagery which is produced with the aid of a computer, or any types of art in which the role of the computer is emphasized. This wide-ranging definition also includes traditional disciplines that use computers - for instance, it encompasses computer-controlled kinetic art (especially sculpture) or computer-generated painting - as well as equivalent forms of applied art (computerized designs, architecture). In any event, it's the latest type of contemporary art - a sort of ultimate postmodernism (retrieved from http://64.130.23.120/computer-art.htm#definition)

- **MOBIUS STRIP**

Mobius Strip is a surface with one continuous side formed by joining the ends of a rectangle after twisting one end through 180°.

- **HYPERBOLIC GEOMETRY**

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Hyperbolic Geometry a non-Euclidean geometry, also called Lobachevsky-Bolyai-Gauss geometry, having constant sectional curvature -1. This geometry satisfies all of Euclid's postulates except the parallel postulate.

In hyperbolic geometry, the sum of angles of a triangle is less than 180 degrees, and triangles with the same angles have the same areas. Furthermore, not all triangles have the same angle sum. There are no similar triangles in hyperbolic geometry. The best-known example of a hyperbolic space are spheres in Lorentzian four-space.

- **EUCLIDEAN GEOMETRY**

Euclidean geometry based upon the postulates of Euclid, especially the postulate that only one line maybe drawn through a given point parallel to a given line. The Euclidean Geometry is based upon five postulates.

1. It is possible to draw a straight line from any point to any point
2. If you have a straight line, it is possible to extend it to any direction to infinity
3. It is possible to draw a circle given any centre and radius
4. All right angles are equal (and congruent)
5. If a straight line crossing two straight lines makes the interior angles on the same side less than two right angles, the two straight lines, if extended indefinitely, meet on that side on which are the angles less than the two right angles.

- **Use the following video to discover the five postulates of Euclidean Geometry**

https://www.youtube.com/watch?v=fv-mDpscZlo

- **STEREOMETRY**

Stereometry deals with the measurements of volumes of various solid figures (three-dimensional figures) including pyramids, prisms and other polyhedrons; cylinders; cones; truncated cones; and balls bounded by spheres

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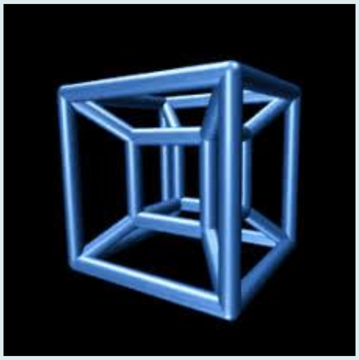
TASK

(I) Given the "Math Behind" Section, let's try to match the mathematical concepts indicated in TABLE A with the pictures in TABLE B, considering that only one picture corresponds to each math concept

TABLE A
A. MOBIUS STRIP
B. EUCLIDEAN GEOMETRY
C. STEREOMETRY
D. HYPERBOLIC GEOMETRY
E. FOUR-DIMENSIONAL GEOMETRY
F. FRACTALS
G. NON-EUCLIDEAN GEOMETRY

TABLE B
1. 

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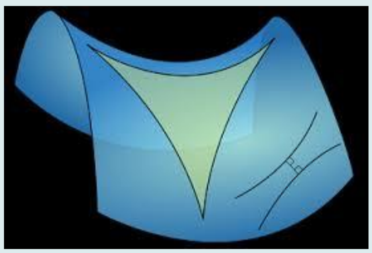
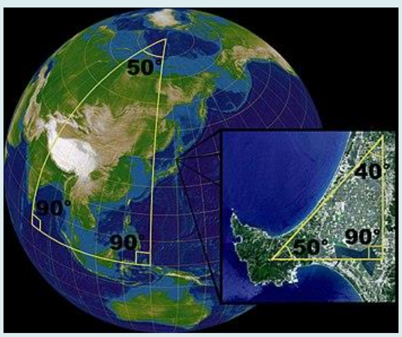
2. 

3. 

4. 

5. 

6. 

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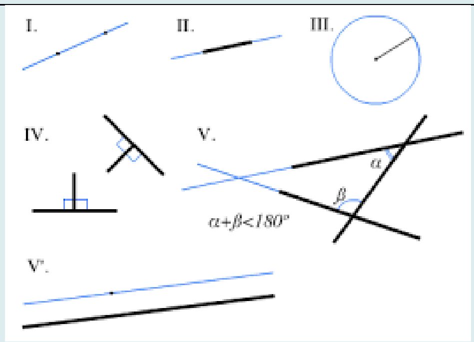
7. 

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