Maths Inspired Escape Room Ideas

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Contents

1 Introduction

In this document, there are 9 full ideas for puzzles, one per subsection. They correspond to different fields of mathematics, I have grouped the puzzles by field in the sections of this document. Attached to this document is a folder with images for the puzzle in Section 2.3. Section 7 contains other ideas for small puzzles or ideas for the event in general. Finally, Section 8 contains mainly the development of an idea about the narrative, that would consist of taking literally the "We want the escape room to reflect mathematical research" and give sentences to the players after solving some of the puzzles saying things about what it is like to do maths (i.e. besides the mathematical products). I would really appreciate if this idea were taken into account, despite not being a puzzle proposal (although as I explain in the section it can be turned into a puzzle). Note it could be compatible with the current narrative. You can find the full ideas for puzzles that I am proposing in Sections 2-6.

2 Geometry

2.1 Similar rectangles

There is an ID card, which is a rectangle whose sides are in some proportion (it does not have to be a real ID card and the proportion does not have to be the golden ratio (it is usually the golden ratio for most cards), in fact it would be better if it is not). You need to find the rectangles whose sides are in that proportion, among several single-color rectangles that are in the room (painted on the walls, objects that you find, made of colored paper (if the rectangles are big there could be just some strips showing only the sides) and on the walls or tables). The colors of the rectangles that have the card's proportion form a code.

In order to figure out which are in that proportion, most of the time you will need to close one eye and move the ID card closely enough to your opened eye to see if it overlaps exactly with the other rectangle. There could also be a couple of rectangles smaller than the ID and you need to use something straight to extend the diagonal of the smaller rectangles and figure if they have that proportion.

There could be a couple of rectangles **on** the ID, and they could be trivially identifiable as having the proportion or not by extending the diagonal as well. In the case that the ID card's sides were in the golden ratio, they could be oriented such that you cannot extend the diagonal but you can notice if the rest of the card is a square.

Additional twist: The id could be fixed at the center of a plastic ball like the one in the image (it is easy to fix it in the center by having a wooden rod or something stuck forming a diameter and then gluing the id). The players cannot open this ball. When this happens, you cannot place your eye arbitrarily close to the ID, so you are not able to tell if large rectangles, on walls for instance, have the ratio or not. You can use this in two ways:

1. Having a large rectangle on the wall such that even if you go to the far end of the

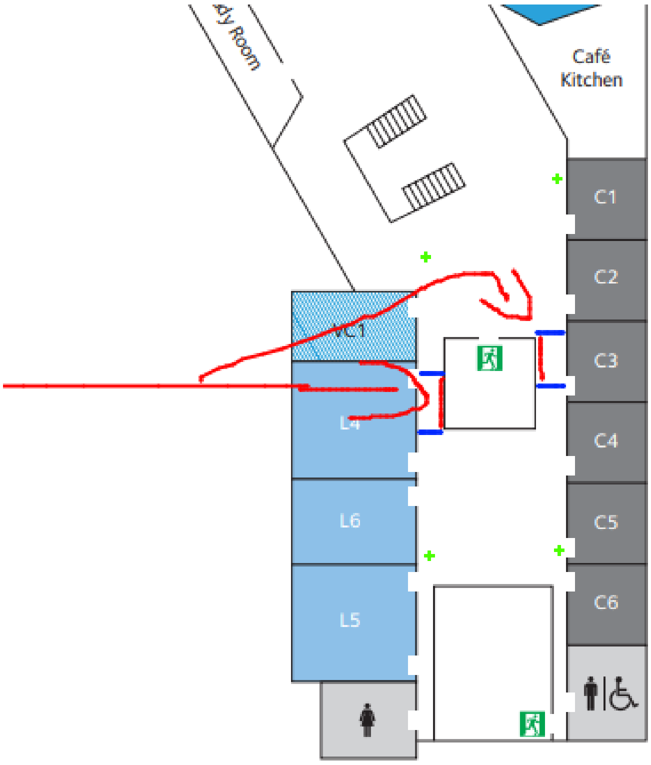
room you cannot tell with the card if it has the right proportion or not. However, going to the corner of the room and aligning the card with the rectangle works. The fact that you can do this might not be obvious for some people because in this case the ray that comes to your eye is not perpendicular to the parallel planes of the card and the rectangle.

2. You could use a mirror to duplicate the maximum observable distance between you and the rectangles on the walls, allowing you to overlap the id with the corners of the rectangle. (This is compatible with the previous variant, since you could also have a rectangle that is so large that you cannot identify if it has the right proportion from the corner of the room). Having a huge fixed mirror or a relatively large movable mirror is not very practical and it is at the risk of it being broken, however, almost all the walls in the MI are reflective, the two large rectangles could be in the two red places indicated by the map and you could use the walls to see the reflection. (In such a case maybe a couple of posters in the department should be temporarily removed). Alternatively, there could be four small mirrors glued to the opposite wall of each large rectangle (or the four of them could work for two rectangles), so if you place yourself with your back touching the wall where the two large rectangles are and you look at the opposite wall, you will be able to move your head a bit until you see the four corners of the rectangle in the four mirrors (this is, like having a huge mirror, but just the important part of it), allowing for the id in the plastic ball to align with them to see if the rectangle sides are in the right proportion. However I think there is no need to use a mirror since the two locations on the map are good for this.

   It would be possible in principle to move to some of the green '+' on the map and check what are the proportions of the big rectangles from there, this can easily be avoided by gluing strips of paper perpendicularly to the walls, where the blue lines are, so you cannot see the upper corners of the rectangles from the green '+'. Not even if you crouch. The rectangles' upper corners are quite high so the strips would also be. People would not touch them with their heads.

In escape rooms, one of the problems of having mechanics that apply to a small number of options (like having only two big rectangles on the wall with the mirror mechanic) is that brute forcing the lock or whatever that is used to check if the code is correct, is an option. To increase the time it takes to brute force the part of the large rectangles, one could have an ordering over the colors, that you find somewhere, and the code is a sequence of letters associated with the colors but this sequence of letters that is the code has to be in increasing order (with the color ordering). In this way, it would take some time to introduce the code in a lock or something similar because you have to shift the combination to agree with the sequence (i.e. if now instead of color A, I have color Z, the sequence shifts and now the first element of the sequence goes to the end of the sequence). Alternatively, if the players do not know how many rectangles are in the code (if for instance you have to introduce it in a Chinese push-button lock), the number of possibilities increases. Another option is to give the players a very simple-to-compute hash-like function (the evaluation of this function would be the code to access the next puzzle) so that computing with pen and paper the function takes 20-30 seconds. The function does not have to be a hash. For instance, give numbers to the colors, add the squares of the numbers and subtract the three colors that are first in the sequence.

Resources: Only rectangles of paper of different colors plus the plastic ball. Plastic



balls can be inexpensive. For instance this one, whose diameter length is 30 cm. This one is bigger but more expensive.

Estimated time: 5 − 8 minutes. Hints should be able to ensure it does not take longer than that time. You can do it even faster if you have two plastic balls with ID cards inside.

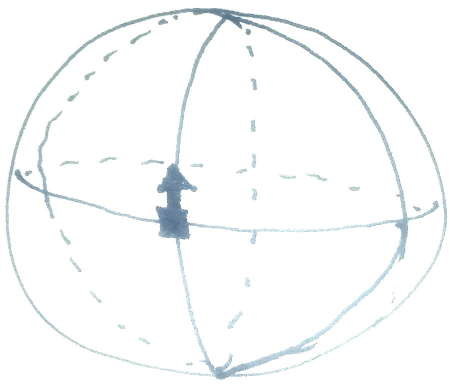
Hints: Suggest them the tricks (see if rectangles coincide with the ID, extend the diagonal of the rectangle smaller than the ID, go to the corner of the room, look at the reflection of the rectangle) if they get stuck.

2.2 Parallel transport on a sphere

This puzzle is to demonstrate parallel transport on spheres (maybe on other surfaces too?). Users are given several rigid wires that have different shapes, all of them are formed by straight segments and turns of 90 or 0 degrees between two consecutive segments. They have at one end attached a flat drink coaster with an arrow or something that indicates that they should place that on top of the table. The arrow will tell the players which direction is forward. The first segment always goes up. They are told that each wire represents a path on a sphere. There is a metallic sphere with a magnet and on the magnet there is an arrow. The sphere has some lines painted that triangulate the sphere into 8 triangles, each of them with three right angles. Any segment going up in the wires is ignored. With the magnet on a vertex of some triangle and the arrow pointing to another, arbitrary vertex, they have to use the segments in the wire that are parallel to the top of the table to move the magnet around the sphere. If the drink coaster has the arrow pointing forward and the second segment (remember the first one goes upwards) goes in that direction and then it turns right and then it goes up and then it is horizontal again but it has turned left with respect to the last horizontal segment (i.e. in the direction of the arrow of the drink coaster) then the players have to move the magnet in the direction of the arrow, then right and then in the direction of the arrow again (but without turning the arrow). They are given two pairs of wires labeled red, red, blue and blue. Pairs with the same color give directions that make the magnet end at the same point and with the arrow pointing in the same direction. For example, a vertical wire and a wire that has 4 segments going forward. Another example is forward, left, backward versus forward, forward, left, backward, left (final position is the same but the arrow turns 90 degrees counterclockwise, see image). Given the two labeled pairs as examples and the instructions about how to move the magnet given the wires, they are told to pair a set of other wires. They have to figure out that the rule is that the magnet has to end at the same point and with the arrow pointing at the same direction and they have to execute the instructions coded in the wire in order to solve the puzzle.

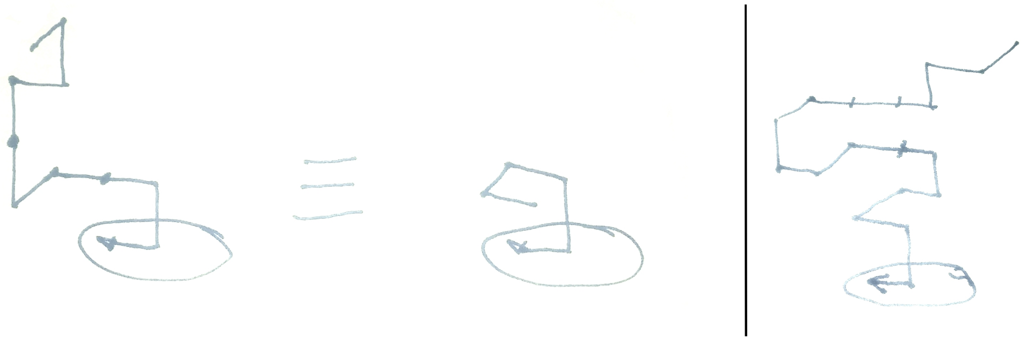
The reason for the three-dimensional wires is that there is no easy way to represent the directions graphically on the plane. Besides, having wires is cool and they are cheap.

In principle it should be possible to do this with other surfaces and in particular with surfaces with negative curvature. For instance, making a piece of the hyperbolic plane like it is done here. But maybe this is just too much.



Triangulated metallic sphere with a magnet and an arrow.

Resources: A sphere. It could be a metallic sphere and a magnet, they are not too



Example of two equivalent wires associated with the original point with the arrow rotated 90 *degrees counterclockwise (left) and an example of a more complex wire, which is associated with the point on the right of where the magnet starts and with the arrow pointing to the south pole (right).*

expensive, for example this one. It is made of stainless steel 304, which it seems it is not very magnetic but it should be enough. It could be any other kind of sphere, it is just that having a magnet makes things easier for the movements.

Estimated time: Can be tuned by deciding how many wires are in the set that the players have to pair.

Hints: Explain to them how to move the magnet in case they do not get the written explanation or help them if they are rotating the arrow when moving the magnet. Tell the players that the aim is to pair wires that make the magnet end at the same place and with the arrow pointing in the same direction.

2.3 Anamorphosis 1: Alignment and Perspective

Anamorphosis is a distorted projection or perspective requiring the viewer to occupy a specific vantage point. There are several different puzzles that can be made using anamorphosis. All of them have beautiful mathematical properties. I am sure the players will be amazed by how one builds the following things and by the effect they produce.

Leveraging the peculiar architecture of the maths building plus the considerable amount of glass that there is everywhere, one thing that can be done is to place colored papers in several glasses, walls, etc so when you are in a very particular point, they align and you see something, like a number for instance. Along with this document I have attached some pictures I have taken and I have superimposed a number on each of them. The number is always in some place such that at least three or four parts of the number can be at different depths. You can see some examples in Section A.

This is a puzzle that is everywhere, it would not belong to any particular location. As I explain in Section 7, it would be a nice instance of something players could be doing while they wait for a particular location to be free, in case that they are fast. They would need to write down on a map from where they see what things, looking at which direction. Being able to see a number only from a very particular point of view produces a quite amazing effect.

It is not even necessary to find all the hidden things. I would do something like saying the players that there are hidden things, that they do not have to find them all, but that unless for every hidden thing there is a team that finds it, everybody will lose.

Resources: Colored papers and some adhesive tape and some time to think exactly what shape the paper has to have so from a particular point it is seen in some way and aligns well with the rest.

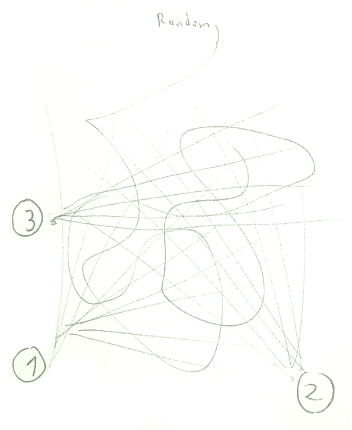
Estimated time: Not too long, it is nonlinear, players can split and search for these things in all the mezzanine. But the point is that it can be a secondary task to solve the problem that teams will have to wait for some locations to be free. As such it wouldn't be needed to finish it.

Hints: No hints allowed. They are just told at the beginning that there are hidden things in the mezzanine and that they have to locate them and write them down on the map and that they can spend the time they are waiting for a location to be free to find them.

2.4 Anamorphosis 2: Linear Deformation

Linear deformation anamorphosis. You can read "LAS MATEMATICAS CONVIERTEN" and "LO INVISIBLE EN VISIBLE" from two different places and angles. Translated from Spanish it would be: "Maths make the invisible visible"

This is a discovery puzzle. There would be a huge poster with doodles on a wall (alternatively doodles on a whiteboard in one room, but it has the disadvantage that the doodle has to be drawn right before the event and by hand). They would be hiding a message using a linear deformation anamorphosis. The idea is to give the code to do the next thing as a sentence encoded in a way similar to the image. In the image, at the beginning you cannot see anything but random lines but if you look from two very particular directions you can read a sentence. In a large wall one could draw something similar but with more than two points to read from, and instead of having all the letters in one direction being parallel they could be written more in a conic-like projection. There could be some random doodles just to hide the message better too. The sentence could be a riddle or just the code.



There could be more than two places from where to read the message and since the doodle will be large the letters could be written in a more conic-like projection.

Resources: Print a big poster or being very patient and skillful to write the doodle onto one of the big whiteboards in one of the rooms. The doodle has to be made with some graphic design software, but it should not be too difficult since it is just rotating and stretching letters.

Estimated time: I cannot really say without testing.

Hints: If players get stuck they can be told subtly that they should look at the image from the right place.

2.5 Anamorphosis 3: Conic / other deformations

Having some reflective different surfaces, images can be encoded so you are not able to recognize them. But placing the right object in the right place you can see the image perfectly. The images could be the code for the next thing. See the image for an example of a conic anamorphosis.

Resources: A reflective cone and possibly other reflective objects and some time to draw some deformed objects. A reflective cone (and other things) can made out of this. Drawing the objects should not be too difficult, I reckon that just by hand and not using any software one can draw things on a paper while looking at the reflection on the cone to make sure the reflected figure looks nice.

Estimated time: As with the other anamorphosis puzzles this is a discovery puzzle and time just depends on how much time players take to realize how they should see things.

Hints can be used to control the time to any upper bound needed.

Hints: Tell subtly the players what some reflective surfaces in the room are for.

3 Number theory

3.1 Ropes whose lengths add up to a number

You have ropes with lengths: $15, 20, 24, 36, 40, 66$ and 96. You need to take a subset that adds to 233 (all but 24 and 40). You can solve this quickly without much brute forcing by realizing that $233 \equiv 1 \mod 2$ and there is only one odd number, so it must be in the sum. $233 \equiv 2 \mod 3$ and all the numbers are $0 \mod 3$ but for 40 that is 1 and 20 that is 2 (so 20 must be in the sum and 40 cannot be). $233 \equiv 3 \mod 5$ and we have three numbers that are $1 \mod 5$ $(36, 66, 96)$ one that is $4 \mod 5$ (24) and the rest are 0. So 24 cannot be in the sum and the others must be in the sum.

This is a list of numbers (with repetitions) that can be obtained with different, wrong configurations such that the results are close to the target, indicating that bruteforcing should not be too easy. 191, 192, 195, 196, 197, 198, 201, 201, 202, 206, 207, 211, 213, 216, 217, 218, 221, 222, 222, 226, 231, 237, 237, 238, 241, 242, 246, 253, 257, 258, 261, 262, 273.

Of course there are many other configurations of numbers to do this trick, just consider a number of modular equations and use the Chinese remainder theorem to obtain all the solutions, one of them will be the target. Then you can add numbers that are 0 (mod the product of all primes considered before but for one prime) and something else mod the other prime so you can satisfy the modular equation. Do this for each equation. Add other numbers that are impossible to be in the sum because for one of the primes in the modular equation it is impossible to combine them to add up to what you want.

You would have a ruler to measure the ropes or labels on them indicating their length. You would have something painted or physical with the target length with a label or something indicating the total length. This is so you can try to concatenate the ropes to try to get to the solution or just work with numbers, whatever you prefer. Of course, the first approach would mean to have to bruteforce the problem, which we have already seen should be quite hard, in principle.

Variant: you have a double-pan balance and an object of some known weight A, you have some other weights $B_1, \dots, B_k$ of unknown weight but you have some other weights $C_1, \dots, C_l$ labeled with their weight so you can figure the weights of the B_i's with the C_i's (C_i's are powers of two, our monetary system...). The code is the subset of weights of the first kind that have the same mass as the weight A.

Resources: Some ropes, better if they are of different colors. Otherwise they can be labeled. Alternatively: a double-pan balance, some weights to play the role of the C_i's and some objects that can be just jars with stuff and we would stuff them to have the weight of the B_i's and A.

Estimated time: I cannot really say how much time it would take for non-mathematicians to solve this. I would say that giving hints at the right times, it would not be more than $10 - 12$ minutes. Mathematicians should solve it in half of that time or less.

Hints (they should be given in this order):

1. "The target is odd and there is only one odd number. What does that mean? What happens with the numbers divisible by 3 ? ".
2. "If you take all the numbers and see their remainder of the division by 3 and you do the same thing dividing by 5 you see that there are ropes that cannot be part of the target."
3. Do the maths for the division by 3 for them.
4. Do the maths for the division by 5 for them.

4 Knot theory / commutators

4.1 Remove one wire so the key falls

This is based on the following theorem, informally stated (see references below): for any $n \in \mathbb{N}^+$ you can hang a picture using n nails such that if you remove any of them the picture falls.

This puzzle would be built for $n = 4$ ($n = 4$ is simple to build, it needs the string to twist 16 times (it is $\leq 2n^2$ in general)). However, instead of having nails and a picture or pushpins on a corkboard with something hanging, it would be more escape room like to have two parallel boards (cardboard, wood, does not matter much) joined by 4 wires and a string tangled with a key hanging (or instead of a key, something the players need to take with them to continue). This is so the key cannot be taken unless one of the wires is removed

Players will be told that they can only remove (or cut?) one wire and that if after doing so they can get the key they will get with it a nice clue to advance (the statement should be deceptive but not false). Otherwise they will have to continue without the clue. **They will not know that any wire works.** They have to remove one wire but they can take as much time as they want to think about which one does the trick. I do not know how to physically enforce this condition so no person needs to be present to arbiter if the solution was right, it would be nice to have a single use wire cutter, something that breaks after cutting a wire (not too convenient because it can break accidentally), but one could just make it simple and have the master of the room removing the wire).

References: This paper and this webpage. You can see in the paper visualizations of the knots for $n = 2$ and $n = 3$ and a very easy algorithm to construct the general solution plus a theorem much more general than the one I stated.

Resources: Two boards, they can be just made of cardboard, and 4 wires. More if we allow players to cut them instead of telling the master of the room to remove the one they pick.

Estimated time: ε, for any $\varepsilon > 0$. They only have to cut one wire and it will work, it is up to the team to decide how much time they want to spend thinking about which one they should cut.

Hints: "Just go for it. After all, you can continue without that key" (of course, they cannot, but they will not know that). Give the hint only if they are spending too much time on it and it does not seem that they want to risk it.

5 Game theory

5.1 Prisoner's dilemma

This event is not an actual escape room and as such not every puzzle that could go in an escape room could go here, but we will have probably more people controlling players, so let's use them.

The idea of this puzzle is that two people, among the volunteers to control the event, kidnap two players of the team that is at a particular location. It works better if it is near the end of the escape room, so it could be after "breaking" the circle of locations. These two players will be separated from the room and from each other. The two kidnappers would explain to the kidnapped people (or they receive a note at the same time they are being kidnapped, see Section 8 for a couple of possible ways to narratively justify this puzzle) that they have to decide between doing action A or action B, they cannot communicate with each other to agree on doing some particular action. If both players do action A they are released and nothing else happens. If only one of them does action A then that player will be released and will get a very good hint to advance quickly (maybe something that lets them skip the last puzzle of the game) and beat the other teams, but the other will stay kidnapped and will not be able to finish the escape room. If both do action B none of them will be able to finish the escape room. They will know all this. Again, see Section 8 to see a narrative justification for this and instances of the actions A and B that make sense. Actually, despite the players not knowing it, if they stay being kidnapped they can be released if they solve an extra puzzle. It is better that this is almost at the end of the escape room or otherwise the players will not want to risk it to remain kidnapped for the rest of the game.

Resources: Two people. Maybe more if indeed this is done very near the end and after "breaking" the circle because more than one team could be in this state at the same time.

Estimated time: Short. It does not matter much since it happens only to two players and at the same time other players of the team are doing other things.

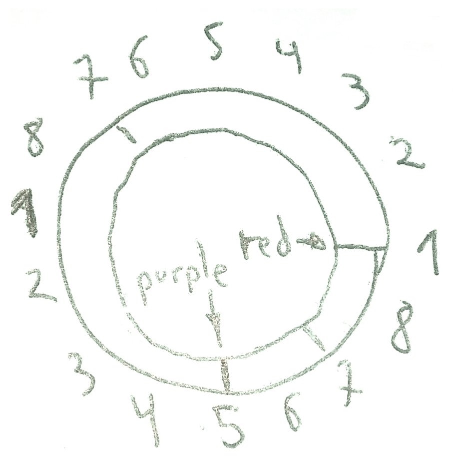
Hints: No hints are provided, just the rules.

6 Miscellanea

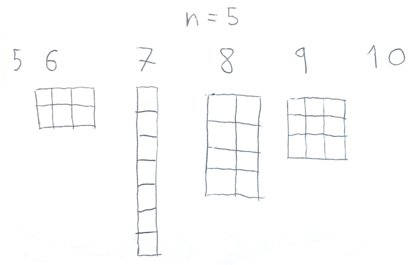
6.1 Find a number in the poster for each statement

This puzzle is about giving hints to find something, like if there was written somewhere "*It seems it is going to rain*" to prompt players to search for something in an umbrella in the room. Well, this is similar but with maths. Players are given a list of several, very simple to understand theorems (without proof), and are told that each of the statements will allow them to find a number in a poster there is in the room. The code could be the set of each number associated to each theorem. More ideas could be used than the ones proposed here. Besides being fun of this puzzle, it aims to give random facts to the players so they are amazed by them if they do not know them, so they get a glimpse of what maths is.

1. *If we color a circle so that the color always changes smoothly, there are always two diametrically opposed points of the same color.* (Maybe rephrase diametrically opposed in a more simple way. Note that I tried not to mention continuity or anything that might sound complicated and unfamiliar) This is an instance of Borsuk Ulam's theorem. I am imagining having a circle and in the outside, around it, there are the numbers from 1 to 8 and then from 1 to 8 again, equispaced going counterclockwise. The circumference is relatively thick and it has for instance the colors of the rainbow changing from red to purple continuously with the usual parametrization during 3/4 of it (from 0 to $3\pi/2$). Then from $3\pi/2$ to 2π you have the colors of the rainbow again but now from purple to red. Then at $3\pi/4$ and $3\pi/4 + \pi$ you have the same color, which will correspond to number 7 (which is the number for the code), assuming the numbers start with 1 being in the x axis. Of course, colors or numbers can be rotated if one wanted to have a different numerical solution. Note that this instance was made so the solution is unique.



2. *For any integer number greater than 1, there is a prime between this number and the double of this number (not including these two numbers).* This is Bertrand's postulate.What a prime number is could be defined in the statement. In the poster there would be something like the image. They will have to infer that 7 is the code for this statement.



Bertrand's postulate for $n = 5$. The rectangles would be a visual aid to identify which number is the prime.

3. *For any polyhedron, the number of faces minus the number of edges plus the number of vertices is always the same number, it does not matter which polyhedron you pick.* This is Euler's formula. The poster would contain a drawing of several polyhedra (some platonic solids, something else...) and players just have to figure out that the constant is 2, and so is the number for the code.

4. *The probability that among* 23 *random people there are two that share a birthday is more than* 50%. This is the birthday paradox. Scattered in the poster there would be names of 23 people with their dates of birth below them. Each date has exactly one digit highlighted. There is exactly a pair of people that share a birthday (day and month are the same, but not the year). The highlighted number for that pair, that would be the same for the two people that share a birthday, is the number for the code.

How to use the code: It could be introduced in a Chinese push-button lock or players could just tell the answer to the master of the room.

Resources: Print a large poster and a bit of time to make the actual poster.

Estimated time: $5 - 8$ minutes. It is highly nonlinear. Actual time depends on the number of theorems that are used and which ones are used.

Hints: The obvious ones. Tell the players that they have to search numbers in the poster using the statements if they do not realize that is what they have to do. And if they get stuck in any of the instances help them with that one in particular, probably just repeating the statement with emphasis on the important thing (e.g. "...that *shaaare* a birthday...").

Other ideas I had about this but that I think they are a bit more complex / far-fetched. I include them here in case someone considers they could be of any use or that a little variation could make them a bit better:

- An instance of Erdős–Szekeres theorem: "If you have a sequence of numbers, all different, of length the square of another number n plus one, there is a subsequence of length n that is always increasing or always decreasing" or maybe simpler, (one always have to think that the audience is not just mathematicians): "In a sequence of 10 different numbers, there is a subsequence of 4 numbers that only increases or only decreases" (or a better, more simplistic phrasing of this). In the poster there could be 4 sequences of length 10 and the 4 numbers that satisfy the theorem would be placed like in the following diagram. Visually, they all together form the number 0.

aa, aa, **aa**, **aa**, **aa**, **aa**, aa, aa, aa, aa

aa, **aa**, aa, aa, aa, aa, **aa**, **aa**, aa, aa

aa, **aa**, aa, aa, aa, aa, **aa**, **aa**, aa, aa

aa, aa, **aa**, **aa**, **aa**, **aa**, aa, aa, aa, aa

- Harmonic conjugates in conics are preserved under projection: You can have 4 points on a line such that $[A, B, C, D] = -1$. You can explain that Alex and Carol have two motorcycles and they go from D to their respective houses A and C. Their motorcycles go at different speeds. In particular they arrive at the same time at their houses. Surprisingly enough, if they start at B they also arrive at their respective houses at the same time. Now, if you project the four points to another straight line using a point, and adjust the speed of the motorcycles so they can go from D to their houses and arrive at them at the same time, then it will always take them the same amount of time to go to their houses from B! It even works if you project the points to a circle and the project back to a straight line. See Figure 1 in Section A for a picture of how what would be in the poster could look like.

- I have always liked the visualization of Fenchel's duality theorem with functions from $\mathbb{R}$ to $\mathbb{R}$. See wikipedia. In particular with a collapsible parallelogram and two parabolas one can see this property quite well. Neumann's min max theorem is also interesting to see with, for instance, a saddle point.

7 Other ideas

These are other ideas, that do not qualify as full puzzles or as puzzles for that matter, but that I considered it was worth including.

- Teams will probably be handed some things (a map of the places indicating where the puzzles are, a notepad, etc). There could be hidden information there. Imagine they are given snacks (walnuts or hazelnuts would work), and some of them have been carefully opened before, a paper with a message has been introduced inside and the shells have been glued again. If they do not try to open them during the game there will be a hint suggesting doing it right before the puzzle that needs what it is inside.

- At some point players could need to write something to solve a puzzle, compute something (like in the ropes puzzle in Section 3.1). At that location, users could have a whiteboard at hand, they will try to erase what is written there and some parts will not be erasable and those will be a code, a riddle or something.

- The format of this event can be quite inconvenient for the teams, since there will be teams that will be faster than others and there will be locations with puzzles that require more time than others. This will cause one team going to a location and having another team still solving the puzzles in that location. The first team could see the solution or they will just have to wait somewhere far. It is something quite inconvenient and that can spoil the tension and the excitement of doing things all the time and compete against the clock. There are several ways to fix this:

- Players are given some puzzles that carry with them and whenever they finish the puzzles at the location where they are they go to the next location, they are told they have to wait and they do it somewhere far but they use that time to solve those puzzles.
- There are puzzles distributed in the mezzanine that are hidden, do not belong to any particular location, and teams have to find and solve them all. The Anamorphosis 1 Alignment and Perspective puzzle explained in Section 2.3 is an example of this type of puzzles. So when teams finish the puzzles at their current location, if the next one is not free they can search for the hidden puzzles and solve them. These puzzles could grant points that would be counted at the end of the game or they could be necessary to finish the escape room (and if you have not done them by when you finish all the puzzles in all the locations you would search for those puzzles). Here it is the problem of communicating the teams that their next location is free while they are who knows where trying to solve this *global* puzzles. There are a couple of ways of solving this problem. The simplest one would be to have in two or three places something with the numbers of the rooms in green or red depending on availability. The masters of each location would send messages to people that change the colors of these objects. The point is that no matter where you are you can see one of these and know if you can go to your next location. In some way, the teams should be urged to go to the locations as fast as they can, not wasting time on the global puzzles when they can go to the next location. This could be done by explaining them that they get a penalty for every minute that passes in which they could be there and they are not (masters would count this and write it down). Another way could be to let the previous team go to that location if they finished the previous one so you have the risk that the location is going to be occupied if you do not hurry and go there when it is free. The other solution for telling the teams that the locations are free could be through an app. For instance, it would not take me more than an hour to program a bot on the instant messaging app Telegram that sends you a private message when the location is free. Masters would interact privately with the bot sending a single message every time a team finish the puzzles in the room and the bot would message automatically the corresponding team to go to the location. That would imply that one of the members of the team should have the app downloaded and that right before starting they would need to send a message to this bot to register as a team in the escape room. But maybe this is overcomplicated especially because I am not sure how good the internet coverage is in the mezzanine.

• The mathematical explanation of things that were in the puzzles could be posted on the event's website, since some people could not get it or given that some puzzles can be based in mathematical properties but both the puzzles per se and the solutions do not necessarily need to require that knowledge. As an example using the puzzles I have proposed, one could have no idea about the problem of the nails and the picture, what parallel transport is or that prisoner's dilemma is. There could be some interested players that would like to read what was the mathematical bit that the puzzles had or what inspired them.

- I think when the event is announced it should be clarified that the event is not actually an escape room. Otherwise it could cause disappointment to some people.

- Credit to Jose Céspedes Martínez for this idea: If the format is going to be indeed a circle of locations with puzzles the way to "break" the circle and end up doing a final puzzle that takes you to the location of the portrait and tunnel could be a puzzle that you will do in your initial location but that you can only do after all the teams have solved the puzzle that is there. That would be implemented with something like the following. Each time a team solves a puzzle at location X, they unlock a piece that stays at location X. When all the teams have solved the puzzle at that location all the pieces can be arranged to form the statement of the final puzzle (that would be the same for every team). He also suggested that, narratively speaking, one could see that every team starts a line of research, that other teams further and contribute to and at the end each team concludes and closes the line of research. This idea inspired the section about the narrative that is below.

8 Narrative and ambience ideas

I am proposing an additional narrative feature for the escape room. This idea is not incompatible with the current one, it can complement it. Narrative in these kinds of events is a very important part of it, the most important one for some people, so I think it would be worth it to spend some time working on that.

The narrative idea I am proposing adding to the escape room takes the "We want the escape room to reflect mathematical research" in the most literal sense. A very cool thing that could be done is to give after the solution of a puzzle (or sometimes with the statement) short sentences. The aim of these sentences is to show what it is like to do research in mathematics (besides of the "mathematical products that are created (or discovered?) by mathematicians") and at the same time these sentences will be related to the puzzles, in the sense that explicitly or figuratively the puzzle is an instance of that sentence. Examples with the puzzles I proposed are provided below. The ultimate aim is to tell people what it is like to be a mathematician without explaining them the actual maths. Things that come with being a mathematician. Almost any puzzle can be linked to a sentence that is related to it and that shows something about research in maths (that would usually be given after a puzzle is solved, so it is not a hint). I am sure that for almost any puzzle that ends up being in the event one can make up a sentence related to it that exemplifies something about what the life of a professional mathematician is like. Each team of players could be a research team. Take into account that these sentences could also be part of a puzzle, since they will be given these sentences on paper, and there could be a hidden message there that they can only read when they have all the sentences, this is, when they have solved all the puzzles at the different locations. Some examples for puzzles I have proposed:

- In the puzzle in Section 4.1, the nails and picture knot puzzle in which any solution is correct: **"Sometimes abstraction makes you spend a lot of time on things that actually were really simple"**.

- Find a number in the poster for each statement, explained in Section 6.1: **"Maths is all about searching for logical truths about anything"**.

- Similar rectangles, explained in Section 2.1: **"You must be creative to solve problems in maths"**. It is referencing the number of tricks needed to solve this puzzle, looking at rectangles with the ID, doing the same such that your vision is not perpendicular to the rectangles, extending the diagonal of smaller rectangles, looking at the reflection of a rectangle, etc.

- Ropes whose lengths add up to a number, explained in Section 3.1: **"Starting with the easy, makes the difficult easy"** This is referring to working with the modular equations instead of the integer equations. This is a sentence I like very much and it is quite representative of many situations that happen when you are solving maths problems. The sentence is my best attempt to translate a quote by this Spanish mathematician, Miguel de Guzmán.

- **Prisoner's dilemma narrative.** Two possibilities: one sticking strictly to the portrait narrative, the other following the variation of the narrative of the research teams and the sentences (which is not incompatible with the other one):

  1. The kidnapping is metaphorical. If they are indeed researchers, they can be called by two people: a CEO of a big company, and a big authority in the university. The two people explain to them separately that they have been following closely the research that they have been doing with their colleague (the other *kidnapped* person) and that they are interested in publishing and giving to that person a huge grant. They receive a note at the same time saying that if they accept the offer and publish their work independently that person will be given in return a big hint (and the other will perish, without a publication, not being able to continue playing the escape room) but if the two of them try to publish their idea independently to these two organizations at the same time, they will know, they will get angry and nobody will get anything and they will not be able to continue with the escape room. On the other hand if none of them accepts the offer they will just go back with their research team and will publish the work together, they will not receive the extra hint. Sentence given along with the puzzle: **"Publish or perish"**.
  2. Two of the thieves kidnap two people. They are given a note saying that they can try to escape or they can give the kidnappers what they want. I am sure there is a good way to narratively link the outcomes of prisoner's dilemma actions to the setting thieves kidnapping you and you trying to escape or just resign.

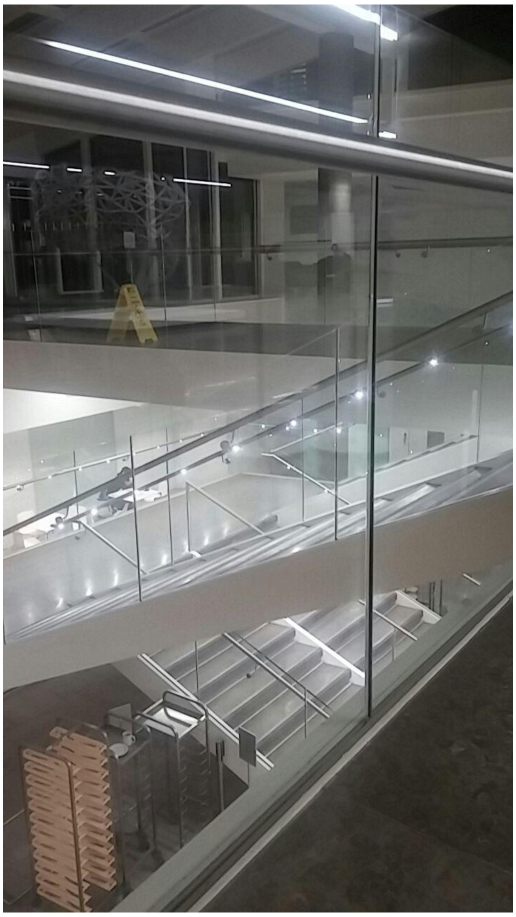
- If there are global things that can be solved by any team and it is needed that all those things are solved by some team (otherwise nobody wins) but the teams have a bonus if they solve them (like a possible way to implement my puzzle Anamorphosis Alignment and Perspective) then a sentence for the narrative could be **"Collaboration is an indispensable part of research"**, although that could go with other puzzles that need several people to solve them or it could go with the idea to "break" the circle explained at the end of Section 7. An alternative sentence for this could be "You are all working towards pushing the boundaries of human knowledge, but sometimes recognition is given to the one that obtains important results".

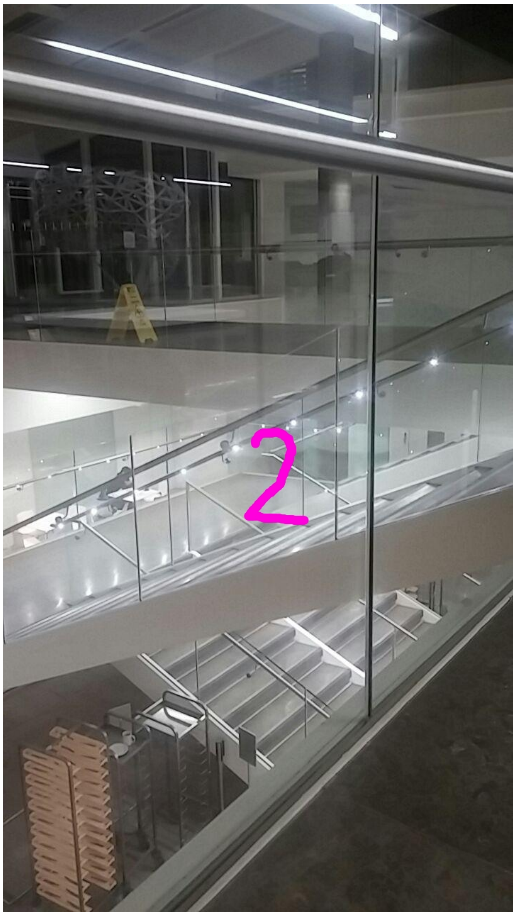
- In any of the anamorphosis puzzles, but especially in the one in Section 2.4 the narrative could say **"Any problem at the beginning is a tangle of which we do not know anything about. But with the right perspective things can become very easy"**.

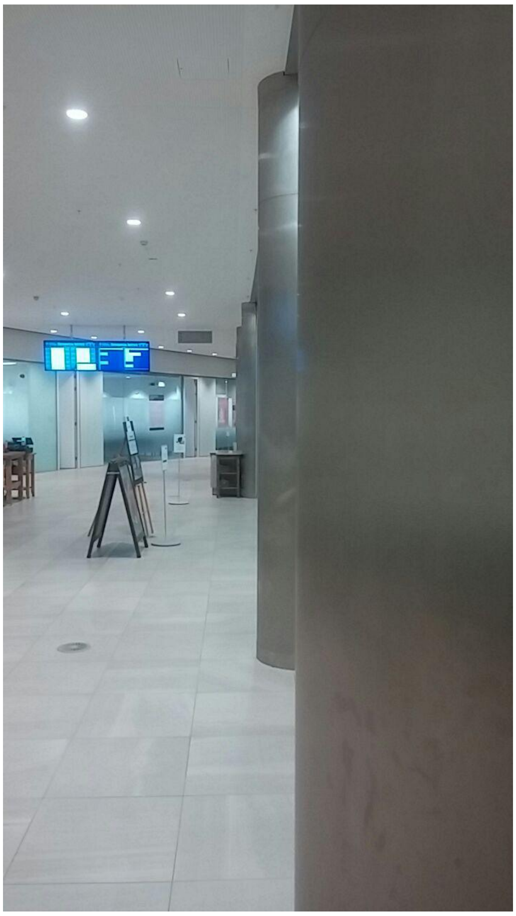
- Nuts with clues inside, as explained in Section 7: **"Sometimes you get ideas inspired by everyday objects or situations"**.
- Whiteboard with unerasable parts: if the whiteboard is given to the players and they are about to use it to perform some computations because some other puzzle requires them to do them, they erase the whiteboard but find that there are some unerasable parts with a new puzzle. A sentence there could be: **"Sometimes when you are trying to solve a problem, you find another problem that is as interesting as the one you were trying to solve"**.
- Other ideas not related to puzzles I have submitted:
  - It is common for escape room like puzzles that they are designed so more than one person in the team must be solving it or otherwise it is physically impossible. If there is a puzzle like that, a sentence to give with the solution is: **"Collaboration is an indispensable part of research"**. This sentence can also go with the final puzzle that *breaks the circle* explained right before this section.
  - Since the players will have to move a lot within the mezzanine to go to the different locations where there are puzzles, after they go to some place you could have a **"Researchers travel a lot"**.
  - If there is some knowledge that the players acquire and that it is used later for the final puzzle or the like, a sentence that could be given is something along the lines of: **"It always feels weird, but the most random things you learn end up being useful in the most unexpected problems"**
- Another idea about the narrative: The escape room could be called "Reality" in posters, the webpage or whatever. Without any mention of the name of the escape room, the players could be explained that they have to be with their research team to further research and figure out how to escape from the room. At the end, when they have finished it (if they have), we could tell them they have successfully "escaped from reality", a feat that mathematicians often accomplish.

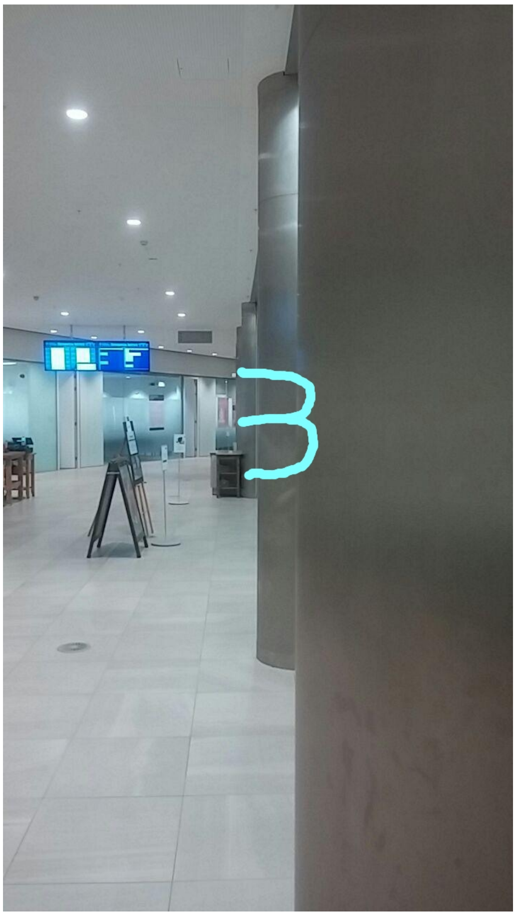
A Pictures for Section 2.3 and for Section 6.1

Regarding Section 2.3: In the folder that contains the pictures there is no picture with number 6 and there are two pink numbers. In the folder there is a map with '+'s of different colors, that indicate where the pictures were taken from. In the case of the two pink ones, they were taken from the ground floor. A couple of examples are shown below.




2




3

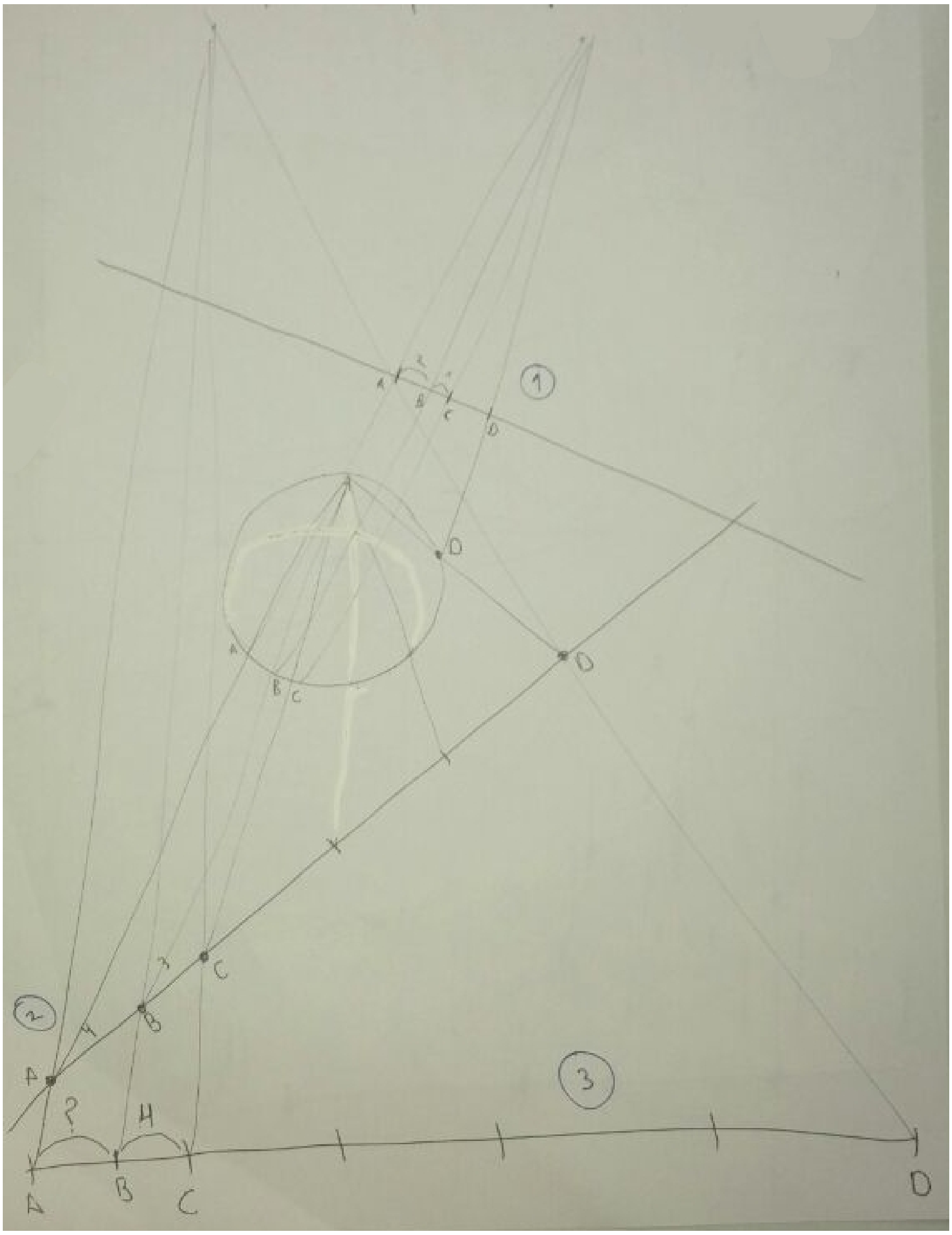


Figure 1: *In the* 4 *points of 3 the marks indicate (and you could easily tell, if it were well drawn) that* $4AC = CD$*. In 2 you can see* $3AC = CD$ *and in 1 it is* $AC = CD$*. There are indications of the values of lengths of some segments, with a lot of redundancy: In 1* $AB = 2$ *and* $BC = 1$*. In 2,* $AB = 4$ *and* $BC = 3$*. In 3,* $BC = 4$ *and you have to figure out the value of* AB *(which is* 5*, since in time* 4 *units you go from* D *to* C *and in time* 5 *units you go from* D *to* A*).*