

# Rubik's Revenge

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The **Rubik's Revenge** (also known as the **Master Cube**) is the 4×4×4 version of Rubik's Cube. Invented by Péter Sebestény, the Rubik's Revenge was nearly called the **Sebestény Cube** until a somewhat last-minute decision changed the puzzle's name to attract fans of the original Rubik's Cube. Unlike the original puzzle (and the 5×5×5 cube), it has no fixed facets: the centre facets (four per face) are free to move to different positions.

Methods for solving the 3×3×3 cube work for the edges and corners of the 4×4×4 cube, as long as one has correctly identified the relative positions of the colours — since the centre facets can no longer be used for identification.



Rubik's Revenge in solved state

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## Mechanics

The puzzle consists of the 56 unique miniature cubes ("cubies") on the surface. However, the center four cubes of each face are merely single square facades hooked into the inner mechanism of the cube. This is the largest change to the 3×3×3 cube, because the centre pieces can move in relation to each other, unlike the fixed centres on the original. The Cube can be taken apart without much difficulty, typically by turning one side through a 30° angle and prying an edge cubelet upward until it dislodges. It is a simple process to solve a Cube by taking it apart and reassembling it in a solved state; however, this is not the challenge.

The original mechanism designed by Sebestény uses a grooved ball to hold the center pieces in place. The edge pieces are held in place by the



Rubik's Revenge in scrambled state

centers and the corners are held in place by the edges, much like the original cube. There are three mutually perpendicular grooves for the center pieces to slide through. Each groove is wide enough for two rows of center pieces, but one side of each groove is shaped to prevent the center pieces from sliding through it, preventing the ball from becoming misaligned with the outside of the cube. Turning one of the center layers moves either just that layer or the ball as well.<sup>[1]</sup>

The Eastsheen version of the cube, which is slightly smaller at 6 cm to an edge, has a completely different mechanism. Its mechanism is very similar to Eastsheen's version of the Professor's cube, instead of the ball-core mechanism. There are 42 pieces (36 movable and six fixed) completely hidden within the cube, corresponding to the center rows on the Professor's Cube. This design is more durable than the original and also allows for screws to be used to tighten or loosen the cube. The central spindle is specially shaped to prevent it from becoming misaligned with the exterior of the cube.<sup>[2]</sup>

There are 24 edge pieces which show two coloured sides each, and eight corner pieces which show three colours. Each corner piece or pair of edge pieces shows a unique colour combination, but not all combinations are present (for example, there is no piece with both red and orange sides, if red and orange are on opposite sides of the solved Cube). The location of these cubes relative to one another can be altered by twisting the layers of the cube, but the location of the coloured sides relative to one another in the completed state of the puzzle cannot be altered: it is fixed by the relative positions of the centre squares and the distribution of colour combinations on edge and corner pieces.

For most recent Cubes, the colours of the stickers are red opposite orange, yellow opposite white, and green opposite blue. However, there also exist Cubes with alternative colour arrangements (yellow opposite green, blue opposite white and red opposite orange).

## Permutations



An Eastsheen cube is on the left, and an official Rubik's Revenge is on the right.



A disassembled Rubik's Revenge, showing all the pieces and center ball.



A disassembled Eastsheen 4x4x4.

There are 8 corner cubelets, 24 edge cubelets and 24 centre cubelets.

Any permutation of the corner cubelets is possible, including odd permutations. Seven of the corner cubelets can be independently rotated, and the eighth cubelet's orientation depends on the other seven, giving  $8! \times 3^7$  combinations.

There are 24 center cubelets, which can be arranged in  $24!$  different ways. Assuming that the four center cubelets of each colour are indistinguishable, the number of permutations is reduced to  $24! / (4!^6)$  arrangements. The reducing factor comes from the fact that there are  $4!$  ways to arrange the four pieces of a given colour. This is raised to the sixth power because there are six colours. An odd permutation of the corner cubelets implies an odd permutation of the centre cubelets, and vice versa; however, even and odd permutations are indistinguishable because of identically coloured centre cubelets.<sup>[3]</sup> There are several ways to make the center pieces distinguishable, which would make an odd center permutation visible.



The 24 edge cubelets cannot be flipped, because the internal shape of the pieces is asymmetrical. The two edge cubelets in each matching pair are distinguishable, since the colours on a cubelet are reversed relative to the other. Any permutation of the edge cubelets is possible, including odd permutations, giving  $24!$  arrangements, independently of the corner or centre cubelets.

Assuming the cube does not have a fixed orientation in space, and that the permutations resulting from rotating the cube without twisting it are considered identical, the number of permutations is reduced by a factor of 24. This is derived from the fact that all 24 possible positions and orientations of the first corner are equivalent because of the lack of face centers. This factor does not appear when calculating the permutations of  $N \times N \times N$  cubes where  $N$  is odd, since those puzzles have fixed centers which identify the cube's spatial orientation.

This gives a total number of permutations of

$$\frac{8! \times 3^7 \times 24!^2}{4!^6 \times 24} \approx 7.40 \times 10^{45}.$$

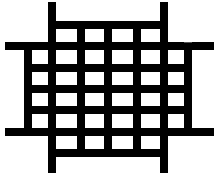
The full number is 7 401 196 841 564 901 869 874 093 974 498 574 336 000 000 000 possible permutations<sup>[4]</sup> (about 7,401 septillion or 7.4 septilliard on the long scale or 7.4 quattuordecillion on the short scale).

Some versions of Rubik's Revenge have one of the center pieces marked with a logo, distinguishing it from the other three of the same colour. This increases the number of distinguishable permutations by a factor of four to  $2.96 \times 10^{46}$ , although any of the four possible positions for this piece could be regarded as correct.

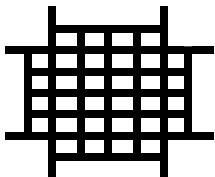
## Solutions

There are several methods that can be used to solve a Rubik's Revenge. The layer by layer method that is

often used for the 3×3×3 cube is usually used on the Rubik's Revenge. One of the most common methods is to first group the center pieces of common colours together, then to pair edges that show the same two colours. Once this is done, turning only the outer layers of the cube allows it to be solved like a 3×3×3 cube. However, certain positions that cannot be solved on a standard 3×3×3 cube may be reached. There are two possible problems not found on the 3×3×3. The first is two edge pieces reversed on one edge, resulting in the colours for that edge not matching the rest of the cubies on either face:



Notice that these two edge pieces are swapped. The second is two edge pairs being swapped with each other:



These situations are known as parity errors. These positions are still solvable; however, special algorithms must be applied to fix the errors.

One of several approaches to solve this cube is to first pair the edges, and then the centers. This, too, is vulnerable to the parity errors described above.

Some methods are designed to avoid the parity errors described above. For instance, solving the corners and edges first and the centers last would avoid such parity errors. Once the rest of the cube is solved, any permutation of the center pieces can be solved. Note that it is possible to apparently exchange a pair of face centers by cycling 3 face centers, two of which are visually identical.

## World records

As of 2009, the world record for 4x4x4 Cube is held by Japanese solver Syuhei Omura with a time of 39.28 seconds set at the Japan Open 2009. The best average time of 45.85 seconds is held by Han-Cyun Chen during the Taiwan Spring Open 2009.<sup>[5]</sup>

## See also

- Pocket Cube (2×2×2)
- Rubik's Cube (3×3×3)
- Professor's Cube (5×5×5)
- V-Cube 6 (6×6×6)
- V-Cube 7 (7×7×7)
- Combination puzzles

## References

- ↑ United States Patent 4421311 (<http://www.freepatentsonline.com/4421311.html>)
- ↑ United States Patent 5992850 (<http://www.freepatentsonline.com/5992850.html>)
- ↑ Cubic Circular Issue 7 & 8 (<http://www.jaapsch.net/puzzles/cubic7.htm#p11>) David Singmaster, 1985
- ↑ Cubic Circular Issues 3 & 4 (<http://www.jaapsch.net/puzzles/cubic3.htm#p14>) David Singmaster, 1982
- ↑ "Official Records of WCA". *worldcubeassociation.org*. <http://www.worldcubeassociation.org/results/regions.php>.

## Further reading

- Rubik's Revenge: The Simplest Solution by William L. Mason
- Speedsolving the Cube by Dan Harris, 'Rubik's Revenge' pages 100-120.
- The Winning Solution to Rubik's Revenge by Minh Thai, with Herbert Taylor and M. Razid Black.

## External links

- Beginner/Intermediate solution to the Rubik's Revenge (<http://www.speedcubing.com/chris/4-solution.html>) by Chris Hardwick
- Rubik's Revenge Solution (<http://www.helm.lu/cube/solutions/revenge/index.htm>) good pictures, pair the edges, and then the centers solution.
- 'K4' Method (<http://rxdeath.com/k4/>) Advanced direct solving method.
- Patterns ([http://www.randelshofer.ch/rubik/patterns\\_revenge.html](http://www.randelshofer.ch/rubik/patterns_revenge.html)) A collection of pretty patterns for Rubik's Revenge
- Program Rubik's Cube 3D Unlimited size (<http://kubrub.googlepages.com/rubikscube>)

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