

# Solving the Rubik's Cube Layer-by-Layer

## Introduction

You can solve the Rubik's Cube. It is simply a matter of breaking the puzzle down into smaller steps and understanding how to approach each step.

### *Cube Anatomy*

The first task in solving the cube is understanding what it is. Inside the cube is an unmoving structure that holds six pieces in place. These six pieces are the center squares on each of the six sides of the cube. Take your cube apart to see for yourself! Around this structure, there are 20 movable pieces: 8 corners and 12 edges. Each corner piece has 3 stickers, and each edge piece has 2 stickers. Solving the cube entails arranging these 20 pieces correctly around the central axes.



Once you understand how the cube is made, you can see why solving the cube side by side would be inefficient. You could solve a side alright, but the relative positions of those pieces 8 pieces (around the unmoving center) could be completely incorrect. It is better to solve the cube layer by layer. This means that as you solve one side, you are simultaneously beginning to solve other sides.

### *Algorithms*

The “trick” to solving the cube is the use of algorithms, or specific sequences of turns. Algorithms do certain things to the pieces of the cube without disrupting other parts of the cube. The more algorithms you memorize, the more tools you have to solve the cube efficiently.

A layer-by-layer approach uses only 6 algorithms (1 for the first layer, 1 for the second layer, 2 for orienting last layer, 2 for positioning last layer) plus their mirrored equivalents on occasion. This method can solve the cube using roughly 110 turns on average.

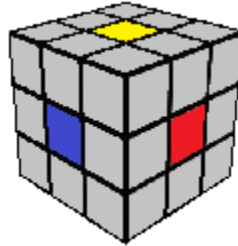
### *Onward!*

Before moving on to the first step, be sure to learn the [notation](#) for single-face rotations.

## The Cross

### Get Your Bearings

The center squares of the cube never move with respect to each other, so they serve as a reference point. We will think of the side with the yellow center as the top. The side with the white center is the bottom, which is the first layer we will solve. By solving the cube from the bottom up, the unsolved portions of the cube remain clearly visible during the solving process.

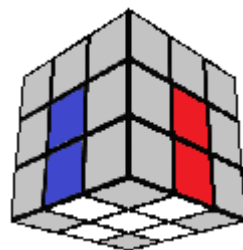


In this diagram, the blue center is on front, the red center is on the right, and the yellow center is on top.

### The Cross

The first step is to make a cross on the bottom layer. You can use any color you like, but many people choose white because it is so easy to see. This tutorial will start with white, so we will make a cross by moving the four edges with white stickers around the white center square.

When we make the cross, the four side color stickers should align with the center sticker on each of the four sides (red with red, blue with blue, etc.). The completed cross is shown in the following two diagrams.



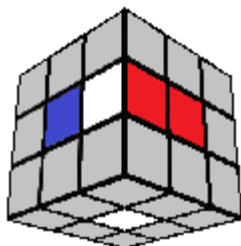
(front)



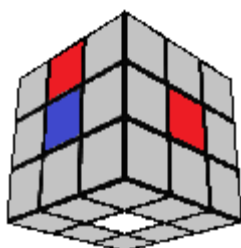
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### The Bad News

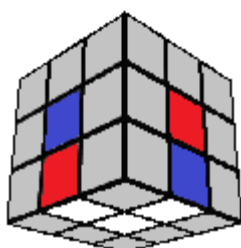
There are no set algorithms used to form the white cross. Here are some situations you may encounter and some ideas which may help you in making the cross.



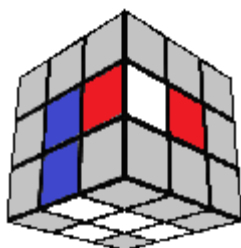
Red is already aligned with red.  
Simply use  $(R')$  to move the white sticker in place.



The red/white edge piece is on the top next to the blue center.  
Use  $(U'R^2)$  to move it into place.  
 $U'$  aligns the red sticker, and  $R^2$  aligns the white sticker.



The white/blue and white/red edge pieces need to switch places.  
One way to fix this is  $(D'F'D^2F)$ .  
 $D'F'$  aligns the blue/white edge and moves it out of the way to the middle layer.  $D^2$  aligns the red/white edge, and  $F$  restores the blue/white edge.  
If other cross pieces are in place,  $(RDR'D'R)$  works.



This is not as bad as it looks. Use  $(D'FD)$ .  
 $D'$  moves the blue/white edge out of our way.  
 $F$  moves the red/white edge to the bottom layer, aligning the white sticker.  $D$  aligns red with the red center while restoring the blue/white edge.

### The Good News

Because this step is entirely intuitive (without algorithms to help) it is actually the hardest step of solving the cube. Once you can make the cross, the rest will seem easier with a little practice! Next we will solve the white corners around the cross.

## The White Corners

In this step, we will move the four corner pieces with white stickers down to their proper place in the bottom layer. There is a short algorithm that helps us do this:  $(RUR')$  and its mirror  $(L'U'L)$ .

Identify a corner in the top layer with a white sticker, preferably one with the white sticker on the side rather than on the very top of the cube.

### Corner on Top, White Sticker on Side

If the white sticker is on the side, turn the top to align the other side color with its center (e.g. red with red), then face that side color.



If the white corner is on the right side of the cube, use  $(RUR')$ .



If the white corner is on the left side of the cube, use  $(L'U'L)$ .

### Corner on Top, White Sticker on Top

If the white sticker is on the very top of the cube, turn the top until the white corner is over an empty slot (that is, over a bottom-layer corner that is not yet solved).



If the white corner is on the right side of the cube, use  $(RU2R')$ .  
Now the white sticker should be on the side in the top layer, so you can follow the instructions above.



If the white corner is on the left side of the cube, use  $(L'U2L)$ .  
Now the white sticker should be on the side in the top layer, so you can follow the instructions above.

### Corner on Bottom

Sometimes there will be no white corners in the top layer, but the bottom layer is not solved. When this happens, turn the cube so that an incorrect white corner is on the bottom front, preferably with the white sticker facing sideways. (This avoids creating a top-facing white sticker.) If the incorrect white sticker is facing down, then it doesn't matter if it is on the bottom front left or bottom front right.



If the white corner is on the right side of the cube, use  $(RUR')$ .  
Now the white sticker should be on the side in the top layer, so you can follow the instructions above.



If the white corner is on the left side of the cube, use  $(L'U'L)$ .  
Now the white sticker should be on the side in the top layer, so you can follow the instructions above.

After all corners are placed correctly around the white cross, the first layer will be complete.



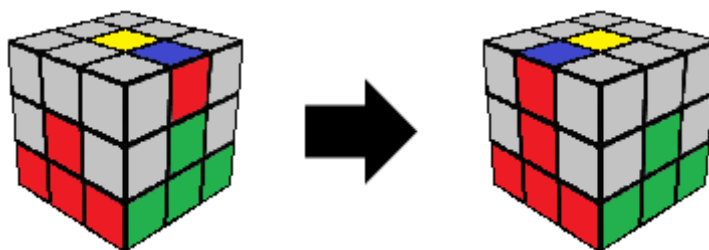
## The Second Layer

Solving an edge in the middle layer entails three steps: align the edge, setup the edge, and solve the white corner. Our second layer algorithm is  $(URUR'U')$  and its mirror  $(U'L'U'LU)$ .

### Align the Edge

Locate an edge piece on the top layer that has no yellow sticker. The edge piece has a top sticker and a side sticker, so be sure to check them both. (If there is no such piece, and the middle layer is not yet solved, skip to Setup.)

Once you have found an edge piece without yellow, turn the top so that the side sticker of the edge piece is aligned with its center (e.g. red with red), and face that side.



### Setup the Edge

Look at the top sticker of the edge piece and the center stickers of the left and right sides to determine where the edge belongs: to the front right slot or the front left slot.



If the edge piece belongs in the front right slot, use  $(URUR'U')$ .



If the edge piece belongs in the front left slot, use  $(U'L'U'LU)$ .

If all the top edges have a yellow sticker, but the middle layer is not solved, simply face a side that has an incorrect edge in the middle.



If the incorrect edge piece is in the front right slot, use  $(URUR'U')$  or simply  $(RUR'U')$  as the initial U is unnecessary. This will bring the incorrect edge piece up to the top layer. Proceed to solving the white corner.

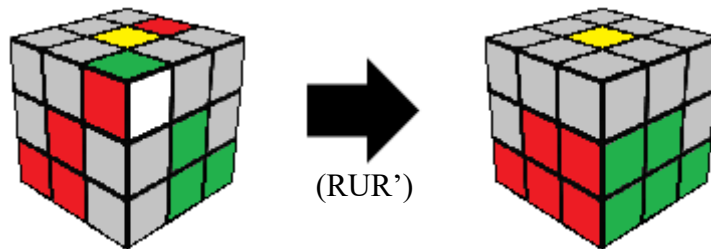


If the incorrect edge piece is in the front left slot, use  $(U'L'U'LU)$  or simply  $(L'U'LU)$  as the initial  $U'$  is unnecessary. This will bring the incorrect edge piece up to the top layer. Proceed to solving the white corner.

Note: The arrangement of yellow stickers in the top layer will vary from the diagrams above.

### Solve the White Corner

When we setup the edge, we put one of the white corners in the top layer. Solve the white corner (the step after the cross), and the middle edge will be solved along with it automatically.



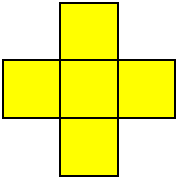
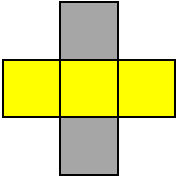
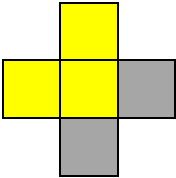
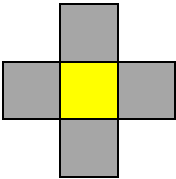
When you place all four middle edges placed correctly, the first two layers will be complete.



## Orient Final Edges

The next step is to make a yellow cross on the last layer. The algorithm we use for this is (F RUR'U' F').

After you finish the first two layers, there are four possible configurations of the top edges (ignoring the corners):

| Yellow Edges | Top View                                                                            | Do This                                                    |
|--------------|-------------------------------------------------------------------------------------|------------------------------------------------------------|
| 4            |    | You already have a yellow cross!<br>Skip to the next step. |
| 2 opposite   |   | F (RUR'U') F'                                              |
| 2 adjacent   |  | F (RUR'U')*2 F'                                            |
| None         |  | F (RUR'U') F'<br>This gives you two adjacent edges.        |

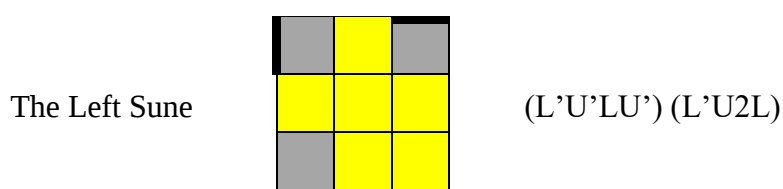
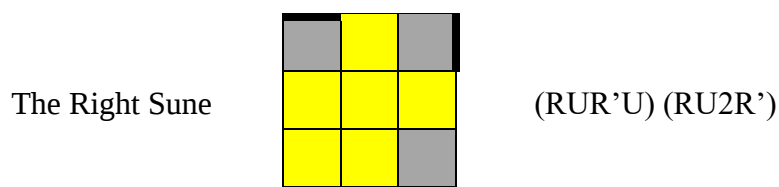
Note: Be sure to orient the top as shown above before using the algorithm.

Once you have a yellow cross on top, you are reading to orient the last layer corners.



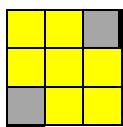
## Orient Final Corners

The next step is to make the top of the cube solid yellow. We will use an algorithm called the Sune (“soo-nay”):  $(RUR'U)(RU2R')$ . We will also use its mirror, the Anti-Sune:  $(L'U'LU')(L'U2L)$ . You can think of these as Right Sune and Left Sune. Here is how they work:

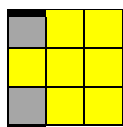


The bold edges represent yellow stickers on the side. If the above scenarios occur, the Sune will orient all the corners, making the top solid yellow.

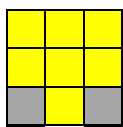
There are five other possible scenarios you may encounter:



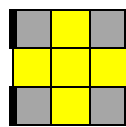
Bowtie



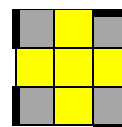
Blinkers



Headlights



Pi

Double  
Headlights

If one of the above five scenarios occurs, do the Right Sune. (Make sure you are facing the side shown above.) This should give you one correctly oriented corner. You can then finish orienting the third layer using either the Right Sune or Left Sune.

Once the top is solid yellow, you are ready to position the last layer corners.



### Position Final Corners

In this step, you will look for sides which have matching corners in the last layer. Matching corners have the same color sticker on one side.



In this diagram, the right side has matching red corners in the top layer.

If there is a side with two matching corners, turn the cube so that side is on the bottom, face the white side, and execute the following algorithm:



(rotate cube)



$(R'UR') D2 (RU'R') D2 R2$

If there is not a side with two matching corners, execute the above algorithm while facing white. This should create a side with two matching corners. Put that side on the bottom, and follow the instructions above.

Once all sides have matching corners, turn the last layer so that the corners line up with the correct sides of the cube.



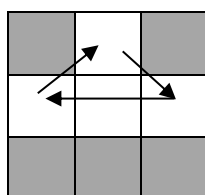
## Position Final Edges

Turn the cube so that yellow is once again on top.

Look to see how many of the four sides of the cube (other than yellow and white) are completely solved. If you are very lucky, all four will be solved, and you're finished! Usually there will be 1 or 0 completed sides. (In other words, there will be 1 or 0 correct edges in the top layer.)

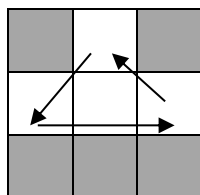
### One Correct Side

If there is 1 correct edge, face the completed side and use this algorithm:



$(M^2U') (M'U^2M) (U'M^2)$

The algorithm shuffles the 3 incorrect edges clockwise. Note that you can change the direction of the shuffle by turning the top clockwise instead of counterclockwise:



$(M^2U) (M'U^2M) (UM^2)$

### No Correct Sides

If there are no correct edges, do the 3-edge shuffle facing any side, and after that you should have one correct edge. Now you can solve the cube using one more 3-edge shuffle.

Congratulations, you have solved the Rubik's Cube! If you memorize these steps, you can solve it consistently with a little practice.



