

Doing Rubik's Cube

by Dick Grune, Aug. 1981

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There are many ways to “do” the Rubik's Cube. The best known ones are by David Singmaster and Donald Taylor. Most methods strive for speed and are complicated; the one presented here is relatively slow but very simple. It requires just four sequences to be learned by heart, and some common sense and spatial insight. By comparison, Singmaster's method requires a minimum of 17 sequences to be memorized.

The Cube has 8 corner pieces with 3 visible sides each, 12 edge pieces with 2 visible sides each, and 6 centre pieces with one visible side each. All pieces can be in the wrong position, except the centre pieces, which are fixed to the frame. Also, if a piece is in the right position, it can still have the wrong orientation (except again for the centre pieces, because they have only one colour).

We restore the cube by rotating the top, front, left, and right faces of the cube, in the way indicated below. We avoid rotating the back plane, and only occasionally rotate the bottom. Top and front are rotated clockwise or counterclockwise. For turning the left and right faces we use the terms “forward” and “backward”. A side face turns “forward” if it turns in the same direction as the wheels turn on a car when you are driving it forward. So the front row goes up, and the top row goes to the back. Likewise for “backward”.

We first correctly position and orientate the 12 edge pieces and then the 8 corner pieces.

The edge pieces

We hold the cube so that the face with the white centre piece is up. We call the colour of the centre piece of the bottom the bottom colour (it is usually yellow).

We restore the edge pieces in three steps: first those in the bottom layer, next those in the middle layer and finally those in the top layer.

The bottom layer.

First we find the four edge pieces that belong in the bottom layer; we can recognize them from having one sticker with the bottom colour. Now we rotate the sides of the cube so that each of the edges is in the *top layer* (we keep the white centre piece up!) Don't mind their orientation for now. Sometimes two sides need to be turned to get one edge piece to the top layer.

The four edge pieces are in the right orientation when their stickers with the bottom colour are on top. If one is reversed, move it to the front by rotating the top layer, and do the following:

rotate the front face clockwise (a quarter turn),
 rotate the top face counterclockwise (a quarter turn),
 rotate the right face forward (so the upper row moves forward)
 (again a quarter turn),

Now it has the right orientation. We repeat this process until all four edge pieces in the top face have the bottom colour sticker up. The top then shows a kind of clover leaf:

	yellow	
yellow	white	yellow
	yellow	

A sequence of turns like this is called an “operator”. A turn is almost always a quarter turn; we will indicate half turns explicitly. Each operator has a specific purpose: the above one, for example, flips the mid front piece over and moves it to the right, but leaves the orientations of the other edge pieces in the top layer unchanged. Though it is important what an operator does, it is equally important what it leaves unchanged.

It is easy to see how this operator works: the piece dives to the right; the location where it should land moves to the right; and then the piece emerges there reversed. The longer operators we will use further on are much harder to fathom, and have to be learned by heart.

We now return to the cube with its bottom colour pieces still in the top layer. Turn the entire cube until the blue centre piece is in front (white stays up!), and turn the top face until the edge piece with a blue sticker is also in front. If we now rotate the front over half a turn, the edge piece arrives at the bottom in the right position in the right orientation. We repeat the action for the three other edge colours; this restores the four edge pieces in the bottom layer. The bottom now shows a kind of “plus”.

The middle layer.

We restore the middle layer by first moving the edge pieces to their correct positions and then, when needed, flip them to the right orientations.

Find in the *top layer* an edge piece that should not be there, i.e., that has no white sticker. Determine its top colour (the colour on the top face of the edge piece). Hold the cube so that the centre piece with that colour is in front (white centre piece stays up!), and rotate the top face so that the edge piece in question also comes to the front. The edge piece now has to go either to the left in the front face or to the right, depending on its other colour. If it should go left, perform the following turns:

left face forward (upper row moves forward),
top face clockwise (piece goes left),
left face backward.

The piece is now correct, both to position and to orientation. This sequence is somewhat similar to the previous one and is equally easy to understand: the prospective position for the piece is moved up, the piece is moved into it, and is then transported back.

If the edge piece should go to the right, we use similar moves using the right face:

right face forward,
top face counterclockwise (piece goes right),
right face backward.

Repeat this for each edge piece that does not belong in the top layer.

Once all middle layer edge pieces are in the middle layer, the whole middle layer is usually, but not always, OK. If you are out of luck and there is still an edge piece wrong in the middle layer, hold the cube so that the problem piece is on the left in the front and do again

left face forward,
top face clockwise,
left face backward.

The problem piece is now in the top layer and the other middle edge pieces are undisturbed. It can now be moved to its correct position in the usual way.

This restores the middle layer without disturbing the bottom layer.

The top layer.

We first orientate the edge pieces in the top layer properly, and then position them.

We *orientate* them correctly as follows (they may even be OK already!). If the top face can be positioned thus:

	white	
white	white	other
	other	

Figure 1

do:

front face clockwise,
top face clockwise,
right face forward,
top face counterclockwise,
right face backward,
front face counterclockwise,

Operator F

and the two “wrong” edge pieces will be correctly oriented. If all four must be flipped or if the offenders are in opposite edges, apply Operator F anyway, possibly even twice (without turning the cube in between), and Figure 1 will appear.

We now bring the edge pieces of the top layer to their correct *positions* (again they may be OK already). Try to turn the cube and/or the top face (white stays up!) such that one of the following figures is obtained,

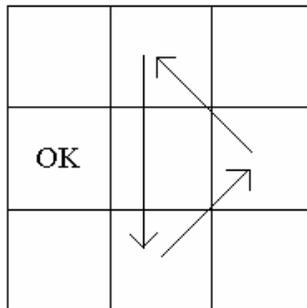


Figure 2a (top view)

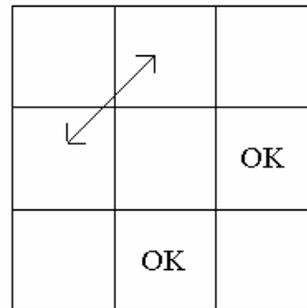


Figure 2b (top view)

in which the arrows show the desired displacements. This may take some puzzling. Then do:

right face forward,
top face clockwise,
right face backward,
top face half a turn,
right face forward,
top face clockwise,
right face backward.

Operator R

If you start from Figure 2b, you will have to give the top face an additional turn. If it is not possible to get one of these figures, apply Operator R anyhow; then it is. This makes all edge pieces OK, both position- and orientation-wise.

We now turn the cube over and repeat the above for the face with the yellow centre piece. This will leave the top and bottom sides with plus signs.

At this point, the cube will have plus signs on all six faces, with *all* side pieces correctly placed and orientated on *all* side. That means we are making headway, but there is also

another advantage: we can now afford to rotate a face before applying an operator. When the operator is finished we can then easily see what face has to be rotated back, and how. This greatly enlarges the applicability of the operators for the corner pieces, which is a good thing.

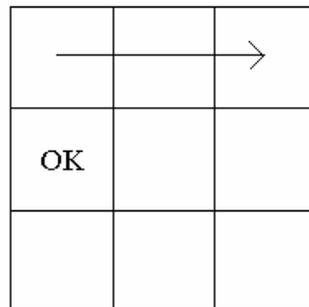
The Operators F and R must be learned by heart. They can be practised by applying them repeatedly to a “clean” cube. After applying the F-Operator six times the cube will be clean again; likewise after 15 times R.

The corner pieces

We restore the corner pieces by first positioning all of them and then orientating them correctly.

The correct position.

Positioning goes as follows. Hold the cube in your hand with the white side—the one that was on top all the time—to the right. Find in the left face a corner piece with a white sticker (so we know it shouldn't be there), and hold the cube with that corner piece in the left back corner of the top face (the white plus stays on the right). We now search the right hand side for the place where it should go and rotate that side so the top looks like this:



(We are free to turn the side, for examining the edge pieces allows us to restore it in one move afterwards.)

We now turn:

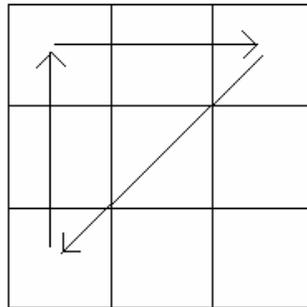
- left face forward,
- top face clockwise,
- right face forward,
- top face counterclockwise,
- left face backward,
- top face clockwise,
- right face backward,
- top face counterclockwise,

Operator L

This moves the corner piece to its position, without disturbing an edge piece. We now turn back the right face if needed so there are plusses again on all sides.

This procedure allows us to transport each white corner piece to its rightful position in the right face —almost always. Occasionally two white corner pieces are already in the right, white face, but swapped. We solve this by replacing one of them by an arbitrary one from the left face, using Operator L. This allows us to proceed as above.

Next we turn to the corner pieces in the left face. We hold the cube so the left side faces upwards. To get the pieces in their proper positions, we first have a closer look at what Operator L does:



If the top face —which used to be the left face— holds one piece in the correct position, we hold the cube so that it is in the unaffected position, the intersection of the top, right and front faces. We now apply Operator L once or twice, until all pieces are in their correct positions. If no piece is in place in the top face, apply Operator L anyhow; now one will be in its correct place. (For practice: Operator L three times on a clean cube.)

The correct orientation

And now for the last step, the untwisting of the corner pieces that remain twisted. This requires the longest operator in our repertoire, Operator B. Operator B acts on two pieces in the top face; it twists the front-right piece 1/3 of a turn to the right (clockwise if you look at it so all three sides are visible) and the back-left piece 1/3 turn to the left:

1/3 cnt. - clockw. turn		
		1/3 clockw. turn

Operator B consists of a set of six turns, repeated twice:

- top face half a turn,
 - front face clockwise,
 - left face forward,
 - bottom face half a turn,
 - left face backward,
 - front face counterclockwise,
- and then a second time.

half of Operator B

We apply this operator to each pair that needs untwisting. To this end, we find two corner pieces, one of which requires a left twist and the other a right twist. Hold the cube so that the one for the right twist is front right in the top face (which now may have any colour). Turn the left or the back face to move the one for the left twist to the position at the back left. Operator B can now serve to correctly untwist both. Finally we turn back the left or the back face; as said, it is easy to see which and how. (To practice: Operator B three times on a clean cube.)

If all pieces require a twist in the same direction, choose an arbitrary pair and apply Operator B. This will untwist only one of them, but allows you to continue with the others.

Repeating Operator B on all pairs of incorrectly oriented corner pieces will untwisted them all, and so restore the cube! Good luck!

Mnemonic:

Each of the four operators starts with a move of a different face, but the second one is always “top face clockwise”:

Operator F: Front face clockwise, top face clockwise, ...

Operator R: Right face forward, top face clockwise, ...

Operator L: Left face forward, top face clockwise, ...

Operator B: Top face clockwise, top face clockwise. ...

(which exactly equals half a turn!)

Note:

We never rotate the back face (OK, almost never), which is a good thing, because it is hard to do that in the right direction. The bottom, another difficult one, only gets half turns, and then clockwise or counterclockwise makes no difference!