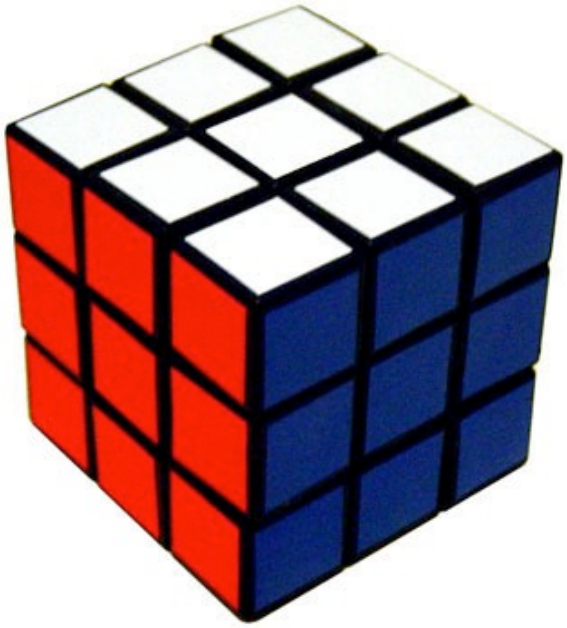

3 X 3 X 3 Rubik's Cube

A Solve Guide

Meant to accompany in-person teaching and demonstration.

[1] Img src: http://www.ymnichka.com/images/01022-01.jpg

Notation (used to reinforce stuff below):

R, F, B, L, etc. correspond to clockwise turns of a face while looking at that face.
R', F', B', L', etc. correspond to counterclockwise turns of a face while looking at that face.
(S, M, and E are chosen arbitrarily to be viewed from the right, top, and front respectively)

From a given "front" then:
R = right up
R' = right down
L = left down
L' = left up
F = front right
F' = front left
D = bottom right
D' = bottom left
U = top left
U' = top right
B = back left
B' = back right
S = center column up
S' = center column down
M = middle row left
M' = middle row right
E = midback right
E' = midback left

General:

This guide is written to accompany and reinforce in-person teaching. The cube is a 3D visual puzzle and is thus difficult to clearly describe on paper without hands-on experience.

For starters, the 3X3X3 can be considered an x, y, z axis system. If you were to remove all of the pieces (turn any face 45º and wedge a finger or tool under one of the 2-sided edge pieces and lift to pop it out, the rest will follow relatively easily. n.b. this is worth doing once to really visualize what you are doing: moving isolated pieces around an axis system), you would be left with a clear x, y, z coordinate set on a very obviously fixed axis. The standard Rubik's color scheme has the white center always opposite the yellow, red opposite orange, and green opposite blue. Further, if white and yellow are + and – along the y axis, the colors will always be red, green, orange, blue as you look down from the white side and continue clockwise. As these center pieces are essentially unmovable and fixed, they are the logical point around which to begin assembling the pieces of the cube.

The other pieces, which (cleverly) attach and rotate freely about this coordinate system, come in two varieties. Edge pieces have just two colors on them, representing the two faces they create the boundary between, there are a total of 12 edge pieces on the cube. Corner pieces have 3 colors on them, corresponding to the three faces they simultaneously belong to, there are 8 corner pieces on the cube. Each of these pieces is defined, and referred to here, by its colors. There is only one Red-Blue edge, just as there's only one White-Blue-Orange corner. There are no White-Yellow edges, nor Red-Green-Blue corners as these faces will never be adjacent. As such, there is only one

specific location on the cube that each of these pieces belongs, when each of them reaches its destination in the right orientation (the red-blue edge can be directly between the red and blue sides but still be in the incorrect orientation), the cube is solved.

The general strategy employed below is to move specific pieces into place in a set order that allows you to accomplish each move easily and without disturbing the pieces you've already put in place. Obviously, as you progress in the solve, there are more pieces that you are potentially displacing when you move the faces of your cube, so the algorithms (fancy word that here means "series of twists and turns that will move around the pieces on the cube" [hopefully in ways you anticipate and desire]) become necessarily more complicated to avoid ruining all the work you've already put in.

A few arbitrary definitions used here before examining the series of steps to put those pieces in place. White is always up in this solve guide. All 6 colors on the cube are equivalent, and the puzzle can be solved from any orientation and with innumerable methods, but for the sake of easy learning and consistency, it is best to eliminate as many of these options as possible. To that end, the white face will always be considered the TOP of the cube. Make an effort to keep the cube firmly in this orientation as you start, as it is very easy to lose track of what you're doing without a secure sense of up and down at the beginning of your solving career. The corollary to this is that the yellow face will always be at the bottom. Since we're working our way down the cube, yellow falls into place as you finish everything else, and so is rarely referred to below. The remaining four colors (red, blue, orange, and green) will take turns being defined as the Front of the cube. These four are referred to as "colors" throughout where white and yellow are just ignored as the arbitrary top and bottom of the cube. Sometimes it is useful to define a piece by its current location on the cube, or to define a place the piece OUGHT to be moved to. This is most easily accomplished with a simple lettering system that corresponds to the layers the pieces belong to. For edge pieces, 2 letters suffice to unambiguously define its location, these letters correspond to the faces that the edge is between given whatever your current definition of "front" is. For corners, 3 letters are needed to define a location. These letters are typically U for Up or the top layer, D for Down or the bottom layer, F for Front or the front face, B for Back or the back face, R for Right or the right face, L for Left or the left face. Look at your cube, white face (as defined by the centers, you'll remember) up, red face as front. Locate the DR edge piece, notice that two corners will be at this intersection. Now locate the UF edge piece – if you've done your cross, this will be a red-white edge – and the BL edge piece. Now located the URF corner, the DLB corner, the DLF corner, etc. Take the time to become acquainted with this notation and concept, it will help to firm up your visualization of the cube.

The set solve order here is: the white cross – assembling all 4 of the edges with white on one face so the white side lines up with the white face and the colored sides align correctly with their respective colored centers; the top corners – placing each of the four corners that have a white side between the appropriate colored sides with white facing up; the middle layer edges – placing each of the 4 "colored" edge pieces into place correctly between their colored center pieces; the bottom corners – placing the corners correctly and then orienting them so yellow faces down; and finally the last layer edges – putting them on the appropriate faces and orienting them with yellow down.

With these concepts and definitions in mind (even loosely) the following solve guide should be readily accessible even without one-on-one work.
Happy Cubing!

To get the white cross:

Remember to keep white as the top. Try to get the edge piece you're working on into the bottom layer, if the white face of this edge piece is on the bottom (i.e., on the yellow face), you can just turn the bottom layer until that edge piece is directly below a vacant spot on the white face and turn the face with the edge piece at the bottom twice in order to get the white edge on top. If the white face of this edge piece is on the outside of the cube, rather than the bottom, position it one 90º turn away from directly under a vacant spot on the cross, i.e., make the desired location of the piece your "front" and turn the bottom around until the white edge piece is in the DR or the DL position. When things are lined up, turn the side that the white piece is on up to move the white edge into either the FR or the FL position, and turn the front to place the edge next to the white center. Then bring the side the piece started on back down to re-place the edge piece that was in the UR or UL position already. The white cross is largely trial and error until you start to understand how the pieces move; this beginning stage is the hardest to learn, and has the steepest learning curve. The understanding you gain here is invaluable later, so work through it and persevere! My experience has been that the first few white cross solutions take anywhere from 5-10 minutes but by the 3rd or 4th solve they become much, much faster.

Once you have the white cross, turn the top to try to match up as many of the colors on your white edge pieces as you can (matching the center pieces of each face to the other color on the white edges) once you have as many as will match – typically either all or two, find an edge that doesn't line up properly with its center, and rotate that face twice. Then rotate the bottom until the white edge piece that you just rotated to the bottom layer matches with the correct center color. When you find the correct face, (where the white piece on the bottom will line up with the center piece of the correct color), rotate THAT face twice. This should put that white edge in the correct place relative to the others that were already correct. It will also put the white edge that had been occupying that spot into the bottom layer so that you can rotate the bottom and match the colors again.

To get the corners on the top layer.

Depending on orientation…

If the white corner is in the **bottom layer and has its white color on a face** (as opposed to on the bottom) match the color on the other face-part of the corner (each corner will have two colors on a face [in this orientation, one of those colors is white] and one on the bottom) to its center piece. When the corner is lined up correctly, use the face that has the white portion of the corner piece on it as the front. Turn the front face towards that corner (if the corner is in the DRF position, turn F to the right, if it's in the DLF, turn F to the left) then turn the bottom in the same direction (either left or right) and the front back the other direction to place the corner between its white edge pieces. On the right this is: FDF'; on the left: F'D'F. This should give you the corners.

After this the rest of the moves are quick tools to put the corners into the position explained above with the piece in the bottom layer and the white color on a face. It is best to start by doing as many as are in the orientation above before proceeding below, as your shuffling of the corners may bring a few more pieces into the easily workable position.

If the white corner is in the **bottom layer and has its white color on the bottom**, rotate the bottom until the corner is directly under where it belongs (this is important to avoid displacing an already correctly-placed corner), then orient the cube so that the

corner is in the DRF position (though obviously either DRF or DRL will work). Perform the following moves: right down, bottom right, right up. Then proceed as above with the new orientation of the corner, which is now in the DBL position. This corresponds to R'DR.

If the white corner is in the **top layer with its white color on the top layer** (as opposed to on a face), orient the cube so that the corner is in the URF position, then turn the right down, bottom left, right up and proceed as above (R'D'R).

If the white corner is in the **top layer with its white color on a face** orient the cube so that the corner's white color is on the front, then turn the side with the white corner down and turn the bottom towards the side that was just turned down and turn the side back up. Proceed as above. If the corner is in the URF position (with white on the front), this is R'DR, if in the ULF: LD'L'.

Congrats! You've done the first layer! Once you feel comfortable doing this quickly and efficiently with a little practice you can move on to layer two!

To complete the second layer:

Choose an edge piece on the bottom layer that does not have yellow as either of its colors. The color on the bottom layer (not on a face, but the color on the yellow face) of this edge piece will be the color of the face you will define as Front. From this front, rotate the bottom so that the piece you are trying to insert is in the DB position. Then turn the front towards the side you are trying to put the edge piece on (this will depend on the color that is on the back face of this edge piece), turn the bottom in the opposite direction, turn the front back to where it was originally, now turn the bottom the same direction you just turned it, and lastly turn the side you're trying to put the piece on (right or left) down, turn the bottom into it, and turn the side back up. If the piece is going to the right this is: FD'F'D'R'DR and if it's going to the left: F'DFDLD'L'

Note: if there are no pieces in the bottom layer that belong in the second layer (i.e. have two non-yellow colors) you may have to use the above move to put a random yellow-containing piece into an edge in the second layer to free up an edge piece, do the move with a random yellow piece in the DB position, targeting the piece that needs displacing (either FMR, or FML)

Congrats! You've finished the second layer! That was the easiest of the layers since it contains immovable centers and just 4 edges that are all equivalent and can be dealt with in the same way. I recommend practicing the top two layers several times, so you pair together the things you've learned about each layer separately into a continuous solve. It's also best to get a night's sleep now and come back to the cube after a break and start again from the beginning a few times to help solidify what you've learned.

When you start to get bored of this Top-two layer strategy, start mixing things up and solving from other colors as top, or solve it from the white face down, but looking at the cube with yellow on top. It is also worth trying to learn to pair corner and edge pieces as you put them in place, this is the method I use to solve these layers, and it is called F2L.

To place the corners correctly:

Find two adjacent corners on the bottom that share a color (other than yellow, of course)… this takes a little practice to see sometimes, and this will hopefully make sense after working on it with me for a while. Turn the bottom so that the two adjacent corners are on the face of that color (though they will not necessarily be rotated correctly). Once the cube is set up correctly, figure out if any of the corners need switching by evaluating whether they are in the appropriate location based on their two non-yellow colors. If there are two corners in need of swapping, orient the cube so that these corners are on the F face (in FRD, FLD) then turn the right down, the bottom left, the right back up. Then the front to the right, the bottom to the right, the front left. And lastly, turn the right down, the bottom right, the right up, and the bottom 2. This corresponds to $R'D'RFDF'R'DRD^2$. Repeat if necessary on other two bottom corners. After each time you do this move, evaluate your corners to see if they are now all appropriately in place (though still not oriented correctly with yellow down).

To orient the corners:

This move will rotate three corners.

If the move is done "on the right side" it is: $R'D'RD'R'D^2RD^2$ and will rotate DRF, DRB, and DLB. Right down, bottom left, right up, bottom left, right down, bottom two, right up, bottom two.
If the move is done "on the left side" it is: $LDL'DLD^2L'D^2$ and will rotate DLF, DLB, and DRB. Left down, bottom right, left up, bottom right, left down, bottom two, left up, bottom two.

Options:

If one corner is correctly oriented, orient the cube so that the correct corner is in either the DRF or the DLF position and the other DF corner has its yellow color on the front face. Then do the move just once on the side with the yellow-faced corner – making the first turn down on the face with that yellow faced corner.

Similar to the top layer corner positioning, the rest of these options are used to get the corners to the above orientation.

If two corners are in the correct orientation and are opposite each other, find a corner with yellow on a face, and do the above move on the side with the correct corner (pull the side down that has the solved corner, while the other corner is showing yellow).

If two corners are in the correct orientation, are adjacent, and have the yellow sides on the same face perform the move on the right side (or the left, doesn't matter) with the face that has yellow faces in the DRF and DLF positions as the front.

If two corners are in the correct orientation, are adjacent, and have the yellow sides on opposite faces, orient the cube so that the solved corners are in the DRF and DRB positions, then do the move on the right, pulling down on the solved corner.

If there aren't any corners correctly oriented, and two of the yellows share a face, while the other two are opposite (the yellows must all be on faces, not the yellow side) orient the two yellows that share a face on the B face, so that there are yellows on the right and left sides of the DF corners, but none showing on the front face. Then do the move on either side, it doesn't matter.

If there aren't any corners correct, and the yellows share opposite faces, orient the cube so that the left and right sides have yellow on the faces, and the front and back have other colors, do the move to either side, it doesn't matter.

At this point, your cube looks pretty good, just 4 pieces remaining, and only two moves left to learn before you can solve the cube consistently and reasonably quickly. Practice all that's above a few more times and sleep on it again, come back after a break, etc.. When you can do everything that's explained above consistently and without confusion or mistakes, you're ready to move on below. It is always possible to just run though this guide to solve it once, but to really learn how to do it consistently (and quickly if it's to serve as a useful party trick!) you should follow the advice I am giving about taking breaks and reinforcing what's above. It's better to be a little frustrated from practicing too much than it is to think you've finished and then realize you've forgotten how to do a step along the way. My trademark in teaching this is person is making you DO IT AGAIN. Practice makes permanent, and muscle memory is quite impressive!

To place all the last layer edges in the correct spots.

You may have to do this move twice to get all the pieces in the correct spots. Find the bottom edge that is already on its face, and use that face as your front (if none are correct use any face as your front and do the move to the right or left and you will reach the situation where one is correct – two and three can never be correct at a time with this face, so it's one, none, or all). If the bottom edge pieces need to be rotated clockwise when viewing the bottom (described as doing the move "to the right" because the long jump across the whole cube is happening to the right), bring the center slice (between the R and L faces) down, turn the bottom to the right, turn the slice back up, turn the bottom twice, turn the slice down, turn the bottom to the right, and turn the slice up (S'DS D^2S'DS). If the edge pieces need to be rotated counter-clockwise when viewing the bottom ("to the left"), do the same move, but each right turn of the bottom layer should instead be done to the left (S'D'S D^2S'D'S).

To flip two adjacent edges and solve the cube.

Short version: Orient the cube so that the edges that need flipping are in the DB and the DR positions.
Then: R'D^2R^{2}DR'D'R'D^2LBRB'L'

Long version: Orient the cube (still with white as top) so that the pieces you need to flip are in the back and on the right of the bottom layer of the cube. The turn the right face down, the bottom twice, the right twice, the bottom to the right, the right down, the bottom to the left, the right down, the bottom twice (two whites should align in the lower right of the front face if done properly), then the left down, the back to the left (counterclockwise from how you should be holding it), the right up, the back to the right, and the left up.

Note: if four edges are flipped, do this twice, if two opposite edges are flipped, do the move from any orientation, then do it again from the orientation described above to solve.

Congrats! Once you have the above memorized, you will be able to solve the Rubik's Cube!