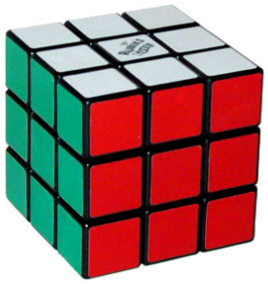
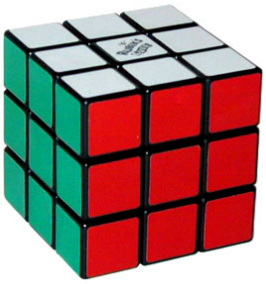
Concord Academy
Mathematical Puzzle & Research Society





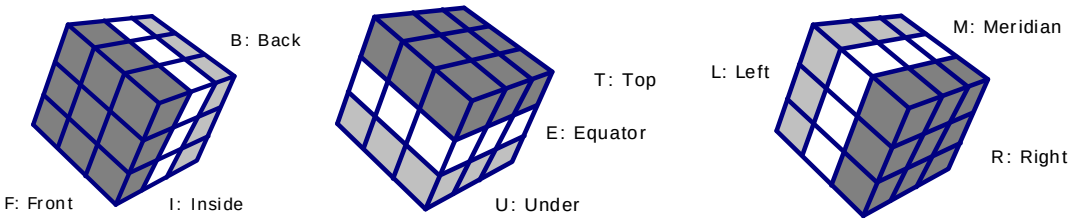
Rubik's Cube: Secrets Revealed

by Selim Tezel

Preliminaries:

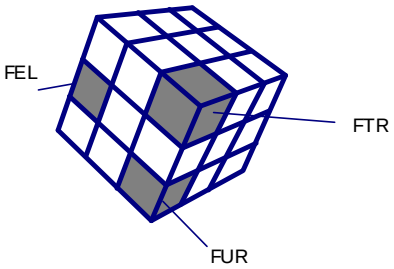
Defining the Faces and Strips:

Front/Inside/Back Top/Equator/Under Left/Meridian/Right



Naming Pieces:

With this notation every piece of the Rubik Cube has a name:



Notation for Rotations:

X+: Turn Face X clockwise X+ +: Turn Face X clockwise twice

X-: Turn Face X counterclockwise X- -: Turn Face X counterclockwise twice

Strip Rotations:

E+: Move Equator Strip clockwise as viewed from Top Face

M+: Move Meridian Strip clockwise as viewed from Right Face

I+: Move Inside Strip clockwise as viewed from Front Face

Principle of "Dualism & Palindromic Restoration":

Take all the steps needed to fix a piece, ignoring the temporary chaos created in the system. Secure the fixed item replacing it with a dual piece and take the exact same steps backwards. Order will return enhanced and chaos will retreat diminished.

This principle will prove to be essential while working on the last face of the Cube.

(1) Fixing the Top Face:

(a) Standard Move: How to Move FUM to FTM ?

U+ M- U- M+

Initial: Top View

U+
"Escape"

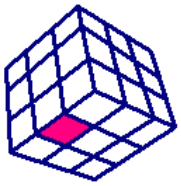
M-
"Come Down"

U-
"Lock to Target"

M+
"Come Up"

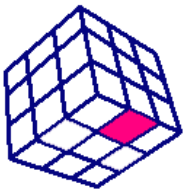
(b) Catapult Move: How to self-swap FUM ?

U+ M- U+ M+

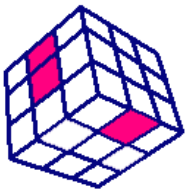


Initial: Bottom View

Initial: Top View



U+
"Escape"



M-
"Come Down"

U+
"Ready to Catapult"

M+
"Come up"

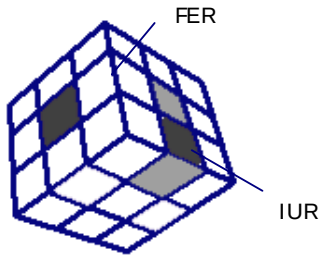
Then use the Standard Move to put the piece into the proper location with the corrected orientation.

Exercise:

Can you find the Standard and Catapult Moves for the corners?

(2) Fixing the Equator Strip:

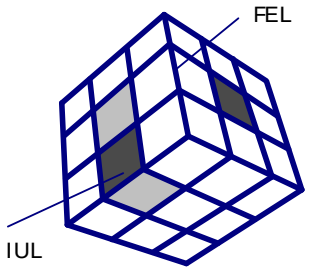
Equator Move I: How to move IUR to FER position?



Assuming Top Face already fixed:
F+ U- M+ U+ M- F- M+ U- M-

Explanation:
F+ U- M+ ("Come Down"; "Lock to Target& Destroy Corner"; "Escape Target")
U+ M- F- ("Fix Corner"; "Return Target" ;"Come up")
Side Effect: Top Face temporarily loses a piece. Fix by:
M+ U- M- ("Fix Top Face by a version of the Standard Move")

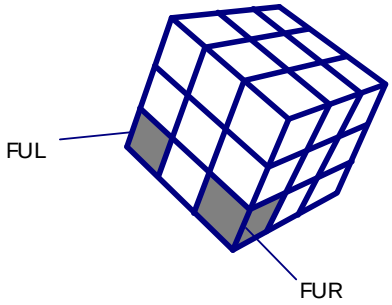
Exercise:
Can you find the Equator Move II to move IUL to FEL?



(3) Fixing the Last Face:

(a) Swapping two corners

Two Corners Swap Move I (Basic): How to swap FUR and FUL?

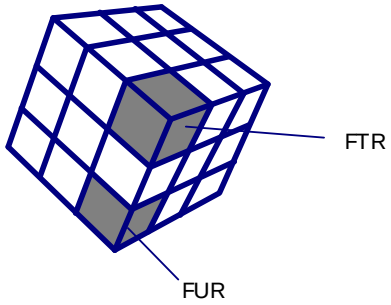


R- U+ R+ U+ F+ U- F-

Side Effect: The fixed Equator loses a piece, fixable by the Equator Move I, II.

Exercise:
Can you find a version of the Corner Swap Move I that will accomplish its task without destroying the fixed Equator?

Two Corners Swap Move II (Basic): How to swap FUR and FTR?
This move is an alternative to **Two Corners Swap Move I (Basic)**



Assumes a face and the equator are fixed. Put the unfixed face in the front

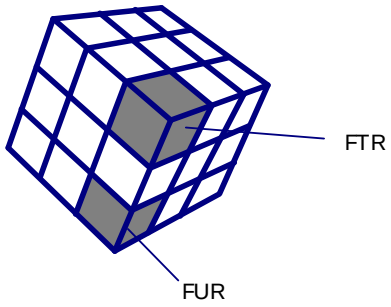
R- F- R+ F+ T+ F+ T-

Side Effect: The fixed Equator loses a piece, fixable by the Equator Move I, II.

Exercise:
Can you find a version of the Corner Swap Move II that will accomplish its task without destroying the fixed Equator?

Two Corners Swap Move II (Advanced): How to swap FUR and FTR without destroying the Equator?

This move is an alternative to **Two Corners Swap Moves I, II (Basic)**



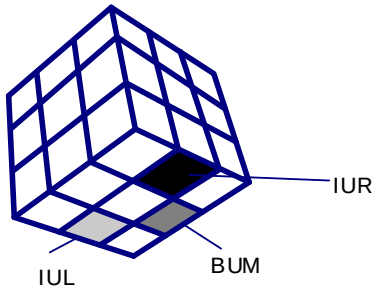
Assumes a face and the equator are fixed. Put the unfixed face in the front

R- F- R+ F+ (T&E)+ F+ T- F- E- F+

(T&E)+ : means **"**move Top and Equator together clockwise"

(b) Positioning the Mid-Pieces

Three Mid-Pieces Rotation Move: How to clockwise rotate IUR, BUM and IUL ?

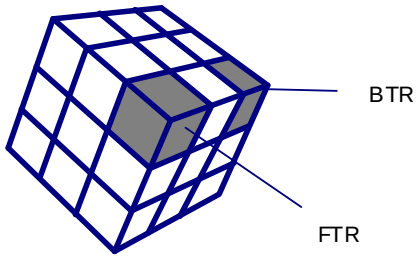


Assumes a face and the equator are fixed. Put the unfixed face at the bottom

M- U+ M+ U- - M- U+ M+

Exercise:
Can you find the move to rotate IUR, BUM and IUL counterclockwise?

(c) Two Corners Self-Rotate Move: How to self-rotate FTR clockwise and then BTR counterclockwise?



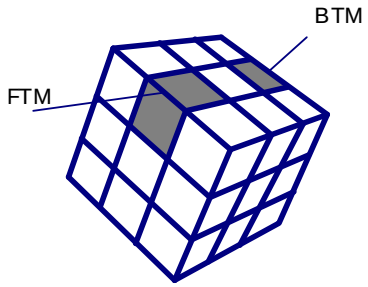
Put fixed Face at bottom, keep the yet-to-be-fixed face up
R- U+ R+ U- R- U+ R+
T+
R- U- R+ U+ R- U- R+
T-

Explanation:
Uses the Principle of "**Dualism & Palindromic Restoration**"

R- U+ R+ U- R- U+ R+ ("Self-rotate FTR clockwise")
T+ ("Escape fixed FTR and put BTR in place")
R- U- R+ U+ R- U- R+ ("Self-rotate BTR counterclockwise by exactly reversing the previous steps, all that was destroyed will be restored")
T- ("Put FTR and BTR in original places)

Exercise:
Can you find a move that self-rotates FTR counterclockwise and then BTR clockwise?

(d) Two Mid-Pieces Self-Swap Move: How to self-swap FTM and then BTM?



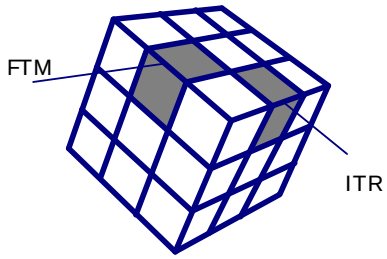
Put fixed Face at bottom, keep the yet-to-be-fixed face up

M- U+ + M+ U+ M- U- M+
T+ +
M- U+ M+ U- M- U- - M+
T- -

Explanation:
Uses the Principle of "**Dualism & Palindromic Restoration**"

M- U+ + M+ U+ M- U- M+ ("Self-swap FTM via Catapult and Standard Moves")
T+ + (escape fixed FTM and put BTM in place")
M- U+ M+ U- M- U- - M+ (Self-swap BTM by exactly reversing the previous steps, all that was destroyed will be restored")
T- - (put FTM and BTM in original places)

Exercise:
Can you find a move that self-swaps FTM and then ITR ?



Recommended Strategy:
Fix a face; fix the equator; put the remaining corners in correct positions, put the mid-pieces in correct positions, orient the corners correctly, orient the mid-pieces correctly.

Rubik's Cube Solution Time Scale:

20 min: Intelligent Beginner
10 min: Expert Cubist
5 min: Master of the Cube
3 min: Speed Demon
1 min: Cube Wizard
less than 1 min: Cube god/goddess or just a Lucky Day!!!

Try to beat these times, discover alternative solutions. We will have Rubik's Cube Olympics soon.

Congratulations you are now one of the select few in the world who knows how to solve the Rubik's Cube!!! Time to look for higher goals!

Rubik's Cube Solution Summary Sheet:

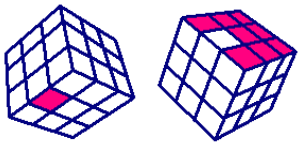
(1)Fixing the Top Face

Standard Move:

U+ M- U- M+

Catapult Move:

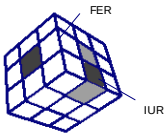
U+ M- U+ M+



(2) Fixing the Equator

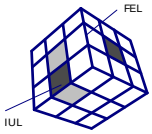
Equator Move I: (placement from right)

F+ U- M+ U+ M- F- M+ U- M-



Equator Move II: (placement from left)

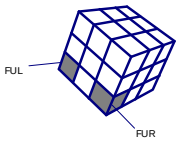
F- U+ M+ U- M- F+ M+ U+ M-



(3) Fixing the Last Face

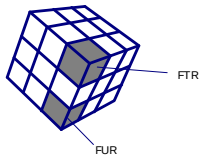
Two Corners Swap Move I (Basic): (damages equator)

R- U+ R+ U+ F+ U- F-

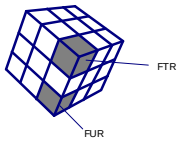


Two Corners Swap Move II (Basic): (damages equator)

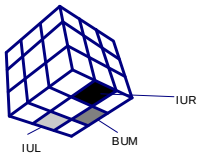
R- F- R+ F+ T+ F+ T-



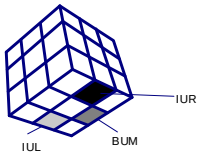
Two Corners Swap Move II (Advanced): (preserves equator)
R- F- R+ F+ (T&E)+ F+ T- F- E- F+



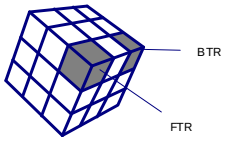
Three Mid-Pieces Rotation Move I: (clockwise)
M- U+ M+ U- - M- U+ M+



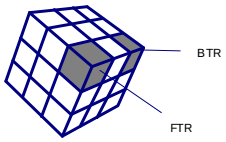
Three Mid-Pieces Rotation Move II: (counterclockwise)
M- U- M+ U+ + M- U- M+



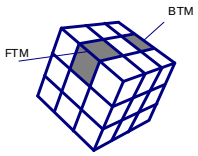
Two Corners Self-Rotate Move I: (clockwise)
R- U+ R+ U- R- U+ R+ T+ R- U- R+ U+ R- U- R+ T-



Two Corners Self-Rotate Move II : (counterclockwise)
R- U- R+ U+ R- U- R+ T+ R- U+ R+ U- R- U+ R+ T-



Two Mid-Pieces Self-Swap Move I: (opposite pieces)
M- U+ + M+ U+ M- U- M+ T+ + M- U+ M+ U- M- U- - M+ T- -



Two Mid-Pieces Self-Swap Move II: (adjacent pieces)
M- U+ + M+ U+ M- U- M+ T+ M- U+ M+ U- M- U- - M+ T-