

# Mathematical & Physical Constants Cube Design

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## Introduction

A **Mathematical & Physical Constants Cube** is a 3x3x3 **Rubik's Cube** used to display the value of some *selected* mathematical and physical constants.

Although the primary usage of this cube is the display of *most common* Constants, it can be also used as a **Number Composer**, but with some limitations however (see the **Numbers Combination Table**).

There are **Virtual Cubes** that can be *virtually* rotated and twisted on a computer screen and **Real Cubes** that can only be *physically* rotated and twisted by hand. A **Texture** is laid down on a Virtual Cube whereas real **Stickers** are stuck down on a Real Cube. A Mathematical & Physical Constants Cube is designed by placing letters and numbers on a texture which is then laid down on a Virtual Cube (see <http://www.randelshofer.ch/> for more details).

### Mathematical & Physical Constants – Useful Links


[http://en.wikipedia.org/wiki/Mathematical\\_constant](http://en.wikipedia.org/wiki/Mathematical_constant)

[http://en.wikipedia.org/wiki/Physical\\_constant](http://en.wikipedia.org/wiki/Physical_constant)

The values of a number of usual constants can be displayed on a *selected* Cube face by rotating and twisting some parts of the Cube. When this has been achieved, we say that the Cube has been *solved*.

The value of  $\pi=3.141592\dots$  is shown on the following example:

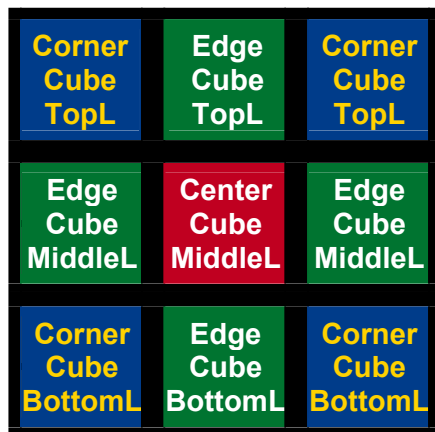
Virtual Mathematical and Physical Constants Cube									
Mathematical & Physical Constants Cube	2	2	8	Copyright © 2008 André Boulouard Walter Randelshofer Werner Randelshofer All rights reserved.					
Original design 2008 by André Boulouard and Walter Randelshofer	1	8	5						
	.	5	6						
	8	4	1	3	.	1	7	3	1
	7	2	6	4	1	5	2	7	1
	1	8	9	2	$\pi$	6	5	7	
			4	0	e	5	9	9	
			7	4	3	6	6	9	
			G	0	3	2	8	P	
	U								
	L	F	R	B					
	D	B							
Mathematical & Physical Constants Cube Texture					Mathematical & Physical Constants Cube				
Download <b>CubeTwister</b> from: <a href="http://www.randelshofer.ch/">http://www.randelshofer.ch/</a>									



Designing a Mathematical & Physical Constants Cube that *works* is definitely not a trivial task but **Design Rules** exist that should be applied. Because it is nearly impossible to test all configurations, the placement of numbers and letters on a texture should be carefully checked at *the end* of the design process. This is carried out by applying a **Design Rules Check (DRC)** in the final design stage.

## Terminology

In a 3x3x3 **Rubik's Cube**, there are 8 *Corner Cubes*, 12 *Edge Cubes*, 6 *Center Cubes* and 6 *Cube Faces*. There are also 4 Corner Cube faces, 4 Edge Cube faces and 1 Center Cube face *per Cube Face*, as shown below.



There are 1 face per Center Cube, 2 faces per Edge Cube and 3 faces per Corner Cube.

There are also 3 horizontal *Layers* called *Top*, *Middle* and *Bottom Layers*.

Cube Lexicon		
English	Français	Deutsch
Cube	Cube	Würfel
cube, cube	cube, petit cube	Würfeteil, Teil des Würfels
face	face	Seite, Seitenfläche
front face	face avant	vordere Seite, vorne
back face	face arrière	hintere Seite, hinten
left face	face gauche	linke Seite, links
right face	face droite	rechte Seite, rechts
top face	face supérieure	obere Seite, oben
bottom face	face inférieure	untere Seite, unten
sticker	étiquette (autocollante), plaquette	Kleber, Farbkleber
tile	tuile, plaquette	Plättchen, Farbplättchen
center cube, center	cube central, centre	Mittelwürfel, Mittelstein, Mitte
edge cube, edge	cube-arête, arête	Kantenwürfel, Kantenstein, Kante
corner cube, corner	cube de coin, coin	Eckwürfel, Eckstein, Ecke
layer	couronne	Schicht, Scheibe
top layer	couronne supérieure	obere Schicht, obere Scheibe
middle layer	couronne intermédiaire	mittlere Schicht, mittlere Scheibe, Mittelschicht, Mittelscheibe
bottom layer	couronne inférieure	untere Schicht, untere Scheibe
orientation, direction	orientation	Orientierung
to solve	résoudre	lösen, zusammen drehen
to twist	pivoter	drehen
to rotate	tourner, effectuer une rotation	drehen
clockwise	dans le sens horaire	im Uhrzeigersinn
anticlockwise, counter-clockwise	dans le sens anti-horaire	im Gegenuhrzeigersinn

# Utilizing Cube Symmetry Properties

A 9 on MC is the same number as a 6 on MC when 180° rotated and vice versa

TL	TC	TR						
ML	MC	MR		9			6	
BT	BC	BR						

A 9 on ML is the same number as a 6 on MR when 180° rotated and vice versa

TL	TC	TR						
ML	MC	MR	9					6
BT	BC	BR						

A 9 on TL is the same number as a 6 on BR when 180° rotated and vice versa

TL	TC	TR	9					
ML	MC	MR						
BT	BC	BR						6

A 9 on TC is the same number as a 6 on BC when 180° rotated and vice versa

TL	TC	TR		9				
ML	MC	MR						
BT	BC	BR						6

A 0 on MC remains the same when 180° rotated

TL	TC	TR						
ML	MC	MR		0			0	
BT	BC	BR						

A 0 on ML remains the same on MR when 180° rotated

TL	TC	TR						
ML	MC	MR	0					0
BT	BC	BR						

A 0 on TL remains the same on BR when 180° rotated

TL	TC	TR	0					
ML	MC	MR						
BT	BC	BR						0

A 0 on TC remains the same on BC when 180° rotated

TL	TC	TR		0				
ML	MC	MR						
BT	BC	BR					0	

Apart from number '0', there are also 5 letters that are invariant when 180° rotated: **H, I, N, O, X**.

# Mathematical & Physical Constants

In this *particular* design, the following **20** mathematical & physical constants values and some *remarkable numbers* can be displayed on a cube.

11 Mathematical Constants		
Constant Name	Abbreviated Name	Truncated Constant Value
Archimedes' constant Pi ( $\pi$ )	$\pi$	3.141592
Golden Ratio ( $\varphi$ )	$\varphi$	1.618033
Napier's constant ( $e$ )	$e$	2.718281
Catalan's constant	C	.9159655
Backhouse constant	C	1.456074
Tribonacci constant	C	1.839286
Lemniscate constant	C	2.622057
Euler-Mascheroni constant ( $\gamma$ )	G	.5772156
$\sqrt{2}$ (Pythagoras' constant)	P	1.414213
$\sqrt{3}$ (Theodorus' constant)	P	1.732050
$\sqrt{10}$ (Pythagorean constant)	P	3.162277
<a href="http://en.wikipedia.org/wiki/Mathematical_constant">http://en.wikipedia.org/wiki/Mathematical_constant</a>		
9 Physical Constants		
Constant Name	Abbreviated Name	Truncated Constant Value
elementary charge	$e$	1.602176 $\times 10^{-19}$ C
Vacuum permittivity ( $\epsilon_0$ )	$e$	8.854187 $\times 10^{-12}$ F·m <sup>-1</sup>
Speed of light in vacuum	C	2.997924 $\times 10^8$ m·s <sup>-1</sup>
Faraday's constant	C	.9648533 $\times 10^5$ C·mol <sup>-1</sup>
Coulomb's constant	C	8.987551 $\times 10^9$ N·m <sup>2</sup> C <sup>-2</sup>
Gravitational constant	G	6.674286 $\times 10^{-11}$ m <sup>3</sup> ·kg <sup>-1</sup> ·s <sup>-2</sup>
Standard Acceleration of Gravity	G	.9806650 $\times 10^1$ m·s <sup>-2</sup>
Planck's constant	P	6.626069 $\times 10^{-34}$ J·s
Proton mass	P	1.672621 $\times 10^{-27}$ kg
<a href="http://en.wikipedia.org/wiki/Physical_constants">http://en.wikipedia.org/wiki/Physical_constants</a>		
Some Remarkable Numbers		
Number	Name	Truncated Value
$\pi \approx 355/113$	$\pi$	3.141592
$\varphi \approx 89/55$	$\varphi$	1.618181
$\varphi \approx 144/89$	$\varphi$	1.617977
$\varphi \approx 233/144$	$\varphi$	1.618055
$\varphi \approx 377/233$	$\varphi$	1.618025
$\varphi \approx 610/377$	$\varphi$	1.618037
$\varphi \approx 987/610$	$\varphi$	1.618032
$\varphi \approx 1597/987$	$\varphi$	1.618034
$\varphi \approx 2584/1597$ (That's it !)	$\varphi$	1.618033
$e \approx 2+5/7$ (5=7-2, $e \approx 2.7$ )	$e$	2.714285
10 9 8 7 6 5 4	C	10987654
8 9 10 11 12	C	89101112
3 5 7 9 11 13	C	35791113
3 9 15 21 27	C	39152127
3 9 81 6561	C	39816561
$(3/2)^{3/2}$	C	1.837117
$(4/3)^{4/3}$	C	1.467523
$(6/5)^{5/6}$	C	1.164084
2/3	C	.6666666
5/3	C	1.6666666
8/3	C	2.6666666
11/3	C	3.6666666
20/3	C	6.6666666
26/3	C	8.6666666
1.111111	C	1.111111
66666666	C	66666666
.9999999	C	.9999999

## Cube Layout

The layout has been designed by placing the *abbreviated* Constant name on the **Right-hand side cube (BR)** of the **Bottom Layer** and the *truncated* Constant value on other cubes, beginning with the **Top Layer Left-hand side cube (TL)**. When the Cube is solved, Constants values should be displayed as shown below:

11 Mathematical Constants shown as displayed on a solved Cube								
Top Layer			Middle Layer			Bottom Layer		
3	.	1	4	1	5	9	2	$\pi$
1	.	6	1	8	0	3	3	$\varphi$
2	.	7	1	8	2	8	1	e
.	9	1	5	9	6	5	5	C
1	.	8	3	9	2	8	6	C
1	.	8	3	9	2	8	6	C
2	.	6	2	2	0	5	7	C
.	5	7	7	2	1	5	6	G
1	.	4	1	4	2	1	3	P
1	.	7	3	2	0	5	0	P
3	.	1	6	2	2	7	7	P

9 Physical Constants shown as displayed on a solved Cube

Top Layer			Middle Layer			Bottom Layer		
1	.	6	0	2	1	7	6	e
8	.	8	5	4	1	8	7	e
2	.	9	9	7	9	2	4	C
.	9	6	4	8	5	3	3	C
8	.	9	8	7	5	5	1	C
6	.	6	7	4	2	8	6	G
.	9	8	0	6	6	5	0	G
6	.	6	2	6	0	6	9	P
1	.	6	7	2	6	2	1	P

Some Remarkable Numbers shown as displayed on a solved Cube

Top Layer			Middle Layer			Bottom Layer		
3	.	1	4	1	5	9	2	$\pi$
1	.	6	1	8	1	8	1	$\varphi$
1	.	6	1	7	9	7	7	$\varphi$
1	.	6	1	8	0	5	5	$\varphi$
1	.	6	1	8	0	2	5	$\varphi$
1	.	6	1	8	0	3	7	$\varphi$
1	.	6	1	8	0	3	2	$\varphi$
1	.	6	1	8	0	3	4	$\varphi$
1	.	6	1	8	0	3	3	$\varphi$
2	.	7	1	4	2	8	5	e
1	0	9	8	7	6	5	4	C
8	9	1	0	1	1	1	2	C
3	5	7	9	1	1	1	3	C
3	9	1	5	2	1	2	7	C
3	9	8	1	6	5	6	1	C



Some Remarkable Numbers shown as displayed on a solved Cube (cont'd)

Top Layer			Middle Layer			Bottom Layer		
1	.	8	3	7	1	1	7	C
1	.	4	6	7	5	2	3	C
1	.	1	6	4	0	8	4	C
.	6	6	6	6	6	6	6	C
1	.	6	6	6	6	6	6	C
2	.	6	6	6	6	6	6	C
3	.	6	6	6	6	6	6	C
6	.	6	6	6	6	6	6	C
8	.	6	6	6	6	6	6	C
1	.	1	1	1	1	1	1	C
6	6	6	6	6	6	6	6	C
.	9	9	9	9	9	9	9	C
A	D	D	N	U	M	B	E	R
								C
								C

# Numbers Combination Table

Numbers Combination Table								
Top Layer			Middle Layer			Bottom Layer		
TL	TC	TR	ML	MC	MR	BL	BC	BR
3	.	1	4	1	5	5	2	π
1	5	7	3	2	1	1	0	φ
.	9	9	7	4	2	8, [8* TR]	3	e
2	0 (0 BC)	4	1	6	9	3	5	C
8	6 (9 BC)	8	5	7	0 (0 ML)	2	1	G
6		6	9	8	6 (9 ML)	7	4	P
			0	9 (6 MC)	[8* (8 ML)]	6 (9 TR)	7	
			8			9 (6 TR)	9	
			2				6 (9 TC)	
			6 (9 MR)					
Numbers that are lacking								
0,4,5,7,9	1,2,3,4,7,8	0,2,3,5	None	0,3,5	3,4,7, [8*]	0,4	8	
Exclusion Rule (DRC)								
Numbers in <b>Red</b> and their counterpart numbers in parentheses <b>cannot</b> be used in the same Constant value.								
Example: a <b>6</b> on <b>Top Center</b> and a <b>9</b> on <b>Bottom Center</b> <b>cannot</b> be used in the same Constant value.								

## Number '8' Case

\* An '8' is composed of 2 loops, the upper loop being usually smaller than the lower loop. If an '8' is to be used flipped over (ie. 180° rotated), it should be redrawn with both loops of the same dimensions.

## Number Composer

Apart from displaying *Constants*, the Cube can also be used as a *Number Composer*, **but with some limitations** however, because there are exclusion rules and numbers lacking on faces. Numbers that can be displayed are displayed with one the following 3 formats:

- 1- NNNNNNNN
- 2- .NNNNNNN
- 3- N.NNNNNN

The *Constant Abbreviated Name* just used before can now be re-used as a *Number Type Specifier*. For example, a **Composed Number** would be displayed with letter '**C**' and an 8-digit **Phone Number** either with greek letter '**φ**' or latin letter '**P**' when used with a **Prefix**.

Number Composer*		
Type of Number	Number Type Specifier	Examples
TBDL**	π	
8-digit <b>Phone Number</b> – without prefix	φ	86924017φ (XX 86 92 40 17)
TBDL	e	
<b>Composed Number: Date</b>	<b>C</b>	10112011 <b>C</b> (10/11/2011)
<b>Composed Number: US SSN</b> – first 8 digits	<b>C</b>	15898555 <b>C</b> (158-98-555X)
TBDL	G	
TBDL	G	
8-digit <b>Phone Number</b> – with <b>Prefix</b>	<b>P</b>	65792134 <b>P</b> (X6 57 92 13 4X)

\* See [Numbers Combination Table](#) for limitations

\*\*To Be Defined Later

# Numbers and Letters Layout

## Center Cubes Layout

There are 6 numbers laid on the 6 center cubes and 7 numbers that can be used: 1, 2, 4, 6 (9), 7, 8

## Corner Cubes Layout

Numbers and letters are *logically* grouped and laid out on the 8 corner cubes as follows:

- 1- Top Left (**TL**): (3,1,.) , (2,8,6)
- 2- Top Right (**TR**): (1,7,9) , (4,8,6)
- 3- Bottom Left (**BL**): (5,1,8) , (3,2,7)
- 4- Bottom Right (**BR**): ( $\pi$ , $\varphi$ ,e) , (C,G,P)

## Edge Cubes Layout

Numbers are *logically* grouped and laid out on the 12 edge cubes as follows:

- 1- Top Center (**TC**): (.,5) , (9 **TC**,2\* **ML**)
- 2- Bottom Center (**BC**): (2,0) , (3,5) , (1,4) , (7,9)
- 3- Middle Left (**ML**): (4,9) , (7,1) , (5,3) , (0,8)
- 4- Middle Right (**MR**): (5,2) , (1,9)

\*This number '2' is placed Middle Left (**ML**) oriented on the *same* cube as number '9', which is **TC** oriented.

## Corner and Edge Cubes DRC

Numbers '0', '6', '9' and '8' (if redrawn), when placed either on a corner or an edge cube may also be used on an opposite cube, ie 180° rotated. The layout should then be checked against *each* Constant in the Table, to ensure that these numbers can be used.

**DRCs** should be applied to the following *opposite* cubes:

- 1- **TL** and **BR** Corner Cubes
- 2- **TC** and **BC** Edge Cubes
- 3- **ML** and **MR** Edge Cubes

Here is an example of a **DRC** applied to Middle Layer edge cubes **ML** and **MR**:

- 1- Middle Left (**ML**): (4 **ML**,9 **ML**) → (4 **ML**,6 **MR**)  
**DRC**: There is *no* Constant in the list that reads XXX4X6XX
- 2- Middle Left (**ML**): (0 **ML**,8 **ML**) → (0 **MR**,8 **ML**)  
**DRC**: There is *no* Constant in the list that reads XXX8X0XX
- 3- Middle Left (**ML**): (0 **ML**,8 **ML**) → (0 **ML**,8 **MR**)  
**DRC**: There is *no* Constant in the list that reads XXX0X8XX
- 4- Middle Right (**MR**): (1 **MR**,9 **MR**) → (1 **MR**,6 **ML**)  
**DRC**: There is *no* Constant in the list that reads XXX6X1XX

Here is another example of a **DRC** applied to the *mixed* case (9 **TC**,2\* **ML**)

- 1- **DRC**: There is *no* Constant in the list that reads X9X2XXXX
- 2- **DRC**: There is *no* Constant in the list that reads XXX2XXX6

If an error is found, then numbers should be *re-arranged*. Here is an example.

In an *earlier* (flawed) layout, numbers were arranged on the Middle Layer, **Middle Left** as follows:

- 1- Middle Left (**ML**): (4,3) , (7,1) , (5,9) , (0,8) — *flawed* layout

Then, it appeared that Catalan's Constant ( $=.9159655$ ) could not be composed on the Cube, because numbers '5' and '9' were on the *same* **ML** edge cube and a '6' **MR** ( $=\underline{9}$  **ML**) was needed just on the opposite **MR** cube: .9159**6**55.

As an *immediate* solution, numbers '3' and '9' were simply *swapped*:

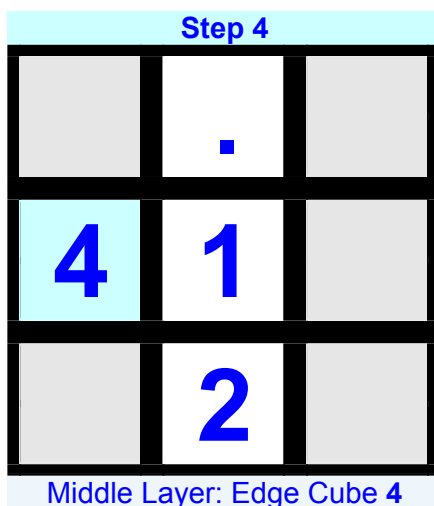
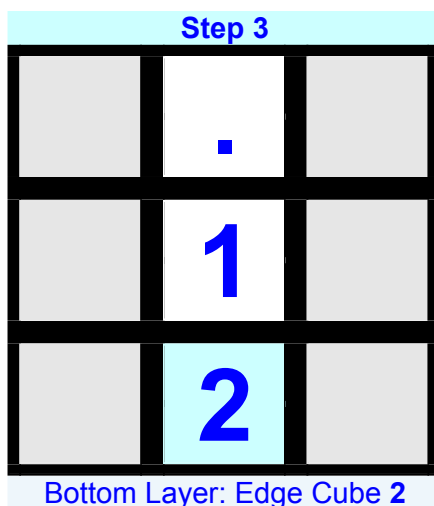
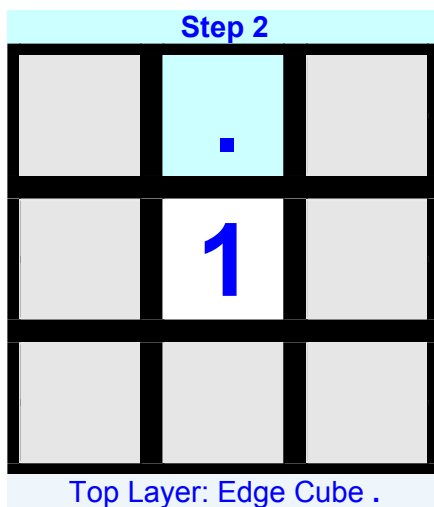
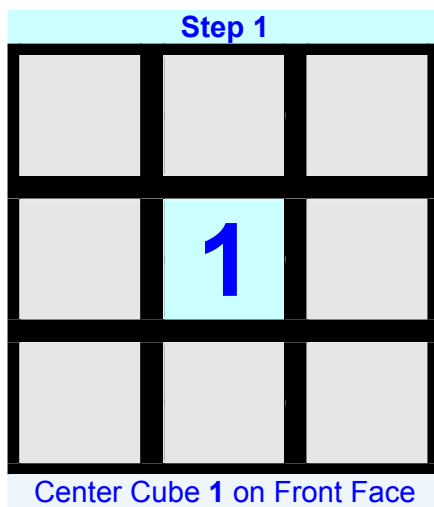
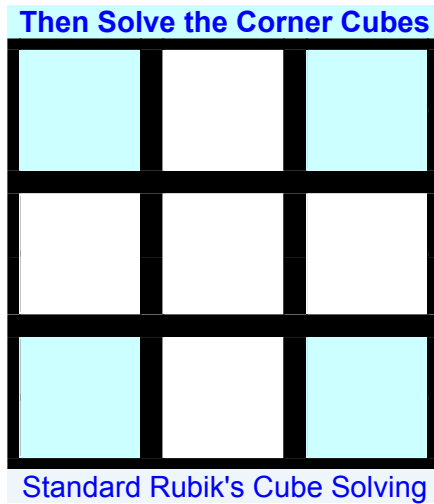
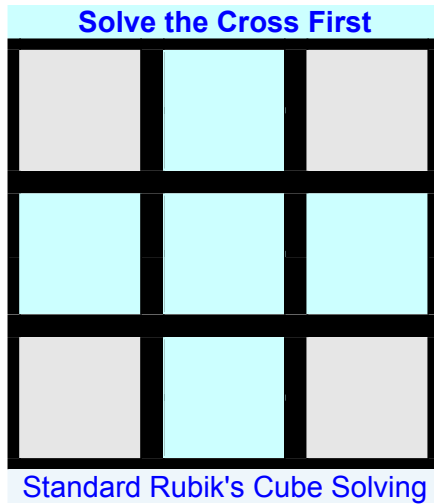
2- Middle Left (**ML**): (4,**9**), (7,1), (5,**3**), (0,8) — *corrected layout*

## Numbers and Letters Orientation – Recap

Numbers and Letters Orientation – Recap		
<b>Top Left</b> – Corner cubes 3, 1, ., 2, 8, 6	<b>Top Center</b> – Edge cubes . , 5, <b>9</b>	<b>Top Right</b> – Corner cubes 1, 7, 9, 4, 8, 6
<b>Middle Left</b> – Edge cubes 4, 9, 7, 1, 5, 3, 0, 8, <b>2</b>	<b>Middle Center</b> – Center cubes 1, 2, 4, 6, 7, 8	<b>Middle Right</b> – Edge cubes 5, 2, 1, 9
<b>Bottom Left</b> – Corner cubes 5, 1, 8, 3, 2, 7	<b>Bottom Center</b> – Edge cubes 2, 0, 3, 5, 1, 4, 7, 5	<b>Bottom Right</b> – Corner cubes $\pi$ , $\varphi$ , e, C, G, P

# Solving a Mathematical & Physical Constants Cube Step by Step

In this example, a step by step solving process is applied to the Mathematical & Physical Constants Cube, just described before. Note that we only need to solve a *single* Face out of six. We will solve a Face for  $\pi$ .



**Step 5**

	.	
4	1	5
	2	

Middle Layer: Edge Cube 5

**Step 6**

3	.	
4	1	5
	2	

Top Layer: Corner Cube 3

**Step 7**

3	.	1
4	1	5
	2	

Top Layer: Corner Cube 1

**Step 8**

3	.	1
4	1	5
9	2	

Bottom Layer: Corner Cube 9

**Step 9**

3	.	1
4	1	5
9	2	$\pi$

Bottom Layer: Corner Cube  $\pi$

**Step 10**

3	.	1
4	1	5
9	2	$\pi$

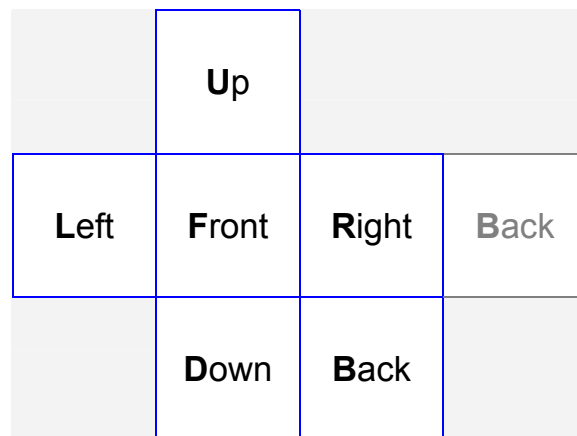
That's it !

Print out this page and fill in the blank faces with *your* data. Then try to design your *own* Cube.

<b>TL</b>	<b>TC</b>	<b>TR</b>						
<b>ML</b>	<b>MC</b>	<b>MR</b>						
<b>BL</b>	<b>BC</b>	<b>BR</b>						

## Corner Cubes Final Check

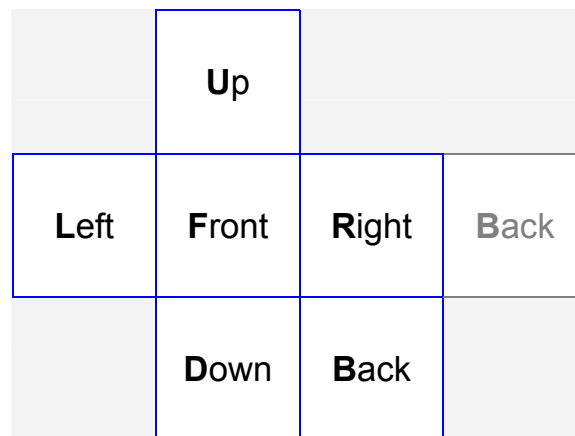
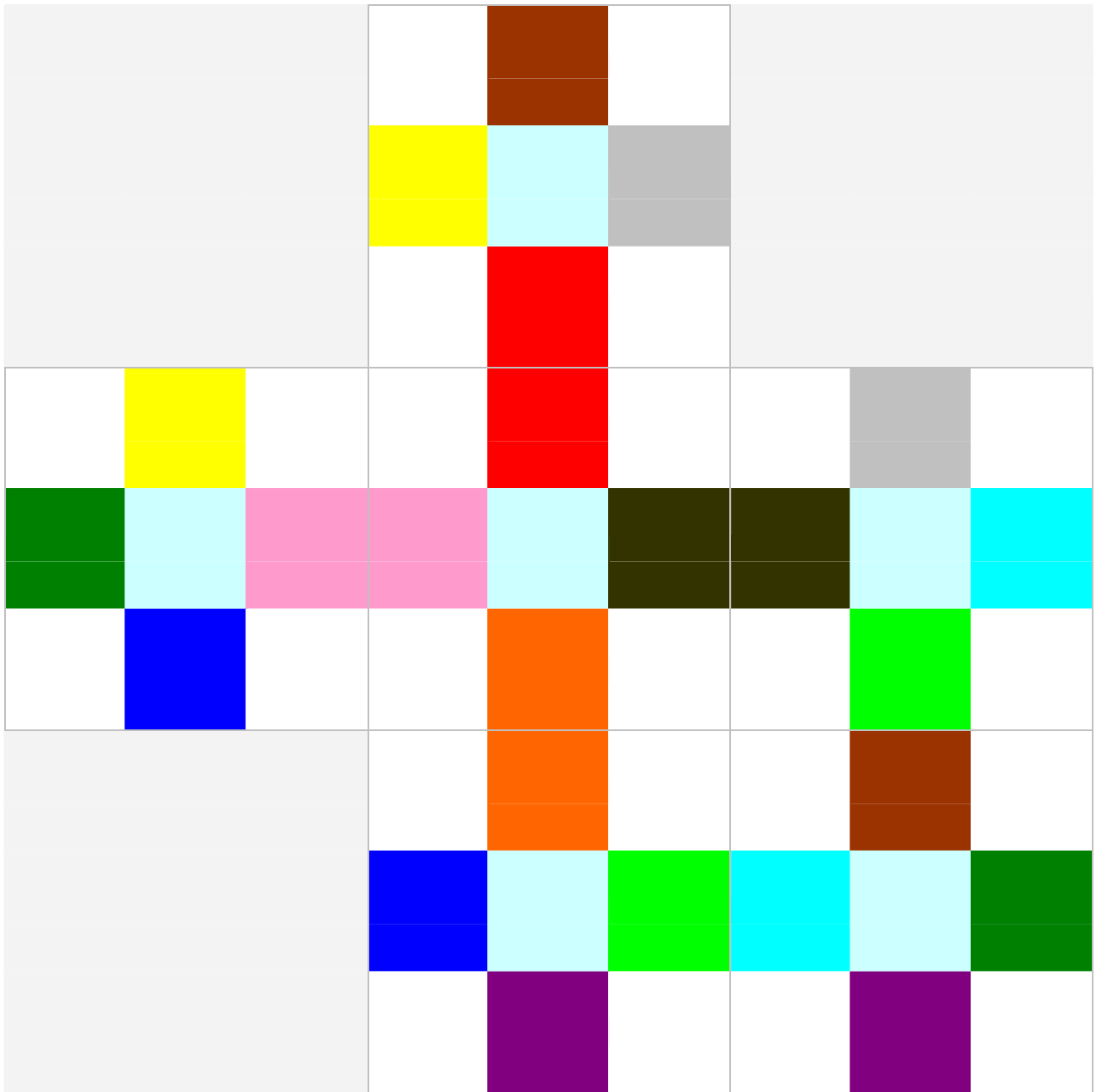
There are 8 Corner Cubes and 3 faces per Corner Cube. In the diagram below, each Corner Cube is displayed in 8 different colors and with the same color applied to each of its 3 faces. This diagram can be used as a convenient *visual aid* to check Design Rules (DRC).





## Edge Cubes Final Check

There are 12 Edge Cubes and 2 faces per Edge Cube. In the diagram below, each Edge Cube is displayed in 12 different colors and with the same color applied to each of its 2 faces. This diagram can be used as a convenient *visual aid* to check Design Rules (DRC).



## Texture Template

This is a texture template that can be printed out and used for writing down numbers and letters by hand *prior to* texture design. All is needed are pencil, rubber...and time.

