

The RUBIKCUBE package

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Abstract

The RUBIKCUBE package provides LaTeX commands and macros for type-setting Rubik cube (3x3x3) notation, configurations, and rotation sequences using the TikZ graphic language. It is part of the rubik ‘bundle’.



Contents

1	Introduction	6
1.1	Requirements	6
1.2	rubikrotation package	6
1.3	Copyright	6
2	Installation	7
2.1	Generating the files	7
2.2	Placing the files	7
2.3	Usage	7
3	TikZ picture environment	8
3.1	ShowCube command	8
3.2	Draw.. error message	9
4	Command conventions	10
4.1	Commands and environments	10
4.2	Capital letters	10
4.3	XYZ argument ordering	10
4.4	Trailing % on the end of commands	10
4.5	Cubies, cubicles, faces and facelets	11

5 Colours	11
5.1 Colour state of the cube	12
6 Rubik cube coordinates	13
6.1 Size of cube minipage	13
7 Rotation commands	14
7.1 Overview	14
7.2 Face rotations	15
7.3 Slice rotations	15
7.4 Wide rotations	16
7.5 Axis rotations	17
7.6 Examples	17
7.7 Backwards compatibility	18
7.8 Listing of all rotation commands	18
8 Other commands	22
8.1 Draw commands	22
8.1.1 Draw.. error message	24
8.2 Face commands	24
8.3 RubikCubeSolved command	25
8.4 RubikCubeGrey command	26
8.5 Slice commands	26
8.6 LayerFace & LayerSide commands	27
8.6.1 LayerFace	27
8.6.2 Draw.. error message	27
8.6.3 LayerSide	27
8.7 Flat commands	31
9 NCube	33
9.0.1 Draw.. error message	33
10 Arrows	33
11 Final example	35
11.1 Without using \RubikRotation	36
12 Known issues & shortcomings	36
13 Acknowledgements	36
14 Future supporting packages	36
15 History	37
16 References	38

17 The code (rubikcube.sty)	40
17.1 Package heading	40
17.2 Some useful internal commands	40
17.3 Colours	41
17.4 ShowCube command	41
17.5 Face commands	42
17.6 RubikCubeGrey command	44
17.7 RubikCubeSolved command	44
17.8 Slice commands	44
17.9 Cube drawing macros	45
17.9.1 Viewing direction	46
17.10 LayerFace commands	51
17.11 DrawFlatX commands	52
17.11.1 DrawFlatXSide commands	57
17.12 SideBar commands	58
17.12.1 Allocating a colour to a single facelet sidebar	58
17.12.2 Drawing a single facelet sidebar	59
17.12.3 Drawing multiple cubie sidebars	60
17.13 NCube command	61
17.14 Drawing single cubies	63
17.15 Text cubies	64
17.16 Rotation commands	65
17.16.1 Introduction	65
17.16.2 Using <code>\join</code>	66
17.16.3 Rotation B	67
17.16.4 Rotation Bp	67
17.16.5 Rotation Bw	67
17.16.6 Rotation Bwp	67
17.16.7 Rotation Bs	68
17.16.8 Rotation Bsp	68
17.16.9 Rotation Ba	68
17.16.10 Rotation Bap	68
17.16.11 Rotation D	68
17.16.12 Rotation Dp	69
17.16.13 Rotation Dw	69
17.16.14 Rotation Dwp	70
17.16.15 Rotation Ds	70
17.16.16 Rotation Dsp	71
17.16.17 Rotation Da	71
17.16.18 Rotation Dap	72
17.16.19 Rotation E	72
17.16.20 Rotation Ep	73
17.16.21 Rotation F	73
17.16.22 Rotation Fp	74
17.16.23 Rotation Fw	74
17.16.24 Rotation Fwp	75

17.16.25	Rotation Fs	75
17.16.26	Rotation Fsp	76
17.16.27	Rotation Fa	76
17.16.28	Rotation Fap	76
17.16.29	Rotation L	76
17.16.30	Rotation Lp	77
17.16.31	Rotation Lw	77
17.16.32	Rotation Lwp	78
17.16.33	Rotation Ls	78
17.16.34	Rotation Lsp	79
17.16.35	Rotation La	79
17.16.36	Rotation Lap	80
17.16.37	Rotation M	80
17.16.38	Rotation Mp	81
17.16.39	Rotation R	81
17.16.40	Rotation Rp	82
17.16.41	Rotation Rw	82
17.16.42	Rotation Rwp	83
17.16.43	Rotation Rs	83
17.16.44	Rotation Rsp	84
17.16.45	Rotation Ra	84
17.16.46	Rotation Rap	85
17.16.47	Rotation S	85
17.16.48	Rotation Sp	85
17.16.49	Rotation Su	86
17.16.50	Rotation Sup	86
17.16.51	Rotation Sd	86
17.16.52	Rotation Sdp	86
17.16.53	Rotation Sl	87
17.16.54	Rotation Slp	87
17.16.55	Rotation Sr	87
17.16.56	Rotation Srp	88
17.16.57	Rotation Sf	88
17.16.58	Rotation Sfp	88
17.16.59	Rotation Sb	88
17.16.60	Rotation Sbp	89
17.16.61	Rotation U	89
17.16.62	Rotation Uw	89
17.16.63	Rotation Up	90
17.16.64	Rotation Uwp	90
17.16.65	Rotation Us	91
17.16.66	Rotation Usp	91
17.16.67	Rotation Ua	92
17.16.68	Rotation Uap	92
17.16.69	Rotations x and xp	93
17.16.70	Rotations y and yp	93

17.16.71	Rotations z and z_p	93
17.16.72	Rotations u and d	94
17.16.73	Rotations l and r	94
17.16.74	Rotations f and b	94

1 Introduction

The RUBIKCUBE package (part of the RUBIK ‘bundle’) provides a collection of L^AT_EX commands and macros for typesetting Rubik cube configurations using the PGF/TikZ graphic languages. Note that this package relates only to the familiar 3x3x3 Rubik cube. We have extended the layer-rotation hieroglyphic notation, originally developed by Garfath-Cox (1981), and improved by Duvoid (2010, 2011).

The RUBIKCUBE package is designed to be used in conjunction with the RUBIKROTATION package (see below); the former deals primarily with typesetting, while the latter processes rotation sequences and keeps track of the cube’s configuration.

The RUBIKCUBE package has been road-tested on a Microsoft platform (with M^IK^TE^X), a Linux platform (Mandriva and T_EXLive), and on a Solaris platform (OpenIndiana).

For the mathematics and group theory associated with the Rubik cube see Chen (2004), Davis (2006), Golomb (1981, 1982), Joyner (2008), Hofstadter (1981), Hutchings (2011), Kociemba web site, Rokicki *et al.* (2013), Tran (2005). Useful web sites for solvers are the Speedsolving website, and those maintained by Duvoid, by Fridrich, by Jelinek, by Reid, and by Vandenburg (see References).

1.1 Requirements

The RUBIKCUBE package requires the TikZ package. In particular, we make use the `\pgfmathsetmacro` command and the TikZ picture environment.

1.2 Supporting tool—the rubikrotation package

The RUBIKROTATION package, is a dynamic extension to the RUBIKCUBE package, and is part of the ‘Rubk bundle’. It consists of the Perl program `rubikrotation.pl` and the associated style option `rubikrotation.sty`. The RUBIKROTATION package implements rotation sequences and random scrambling of the 3x3x3 Rubik cube on-the-fly using a `\RubikRotation{<rotation-sequence>}` command. It returns the new state in a form which is then used by the RUBIKCUBE package.

Since the `\RubikRotation` command works by CALLing the `rubikrotation.pl` program, it follows that the RUBIKROTATION package requires (a) Perl to be installed, and (b) L^AT_EX needs to be run using the `--shell-escape` commandline option. See the RUBIKROTATION documentation for details.

1.3 Copyright

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2 Installation

2.1 Generating the files

Place the file `rubikcube.zip` into a temporary directory, and unzip it. This will generate the following files:

```
rubikcube.ins
rubikcube.dtx
rubikcube.pdf
Rubik-doc-figA.pdf
Rubik-doc-figB.pdf
Rubik-doc-figC.pdf
Rubik-doc-figD.pdf
Rubik-doc-figE.pdf
Rubik-doc-figF.pdf
```

The style option `rubikcube.sty` is generated by running (pdf)L^AT_EX on the file `rubikcube.ins` as follows:

```
pdflatex rubikcube.ins
```

This documentation file (`rubikcube.pdf`) can then be generated using the following steps¹:

```
pdflatex rubikcube.dtx
pdflatex rubikcube.dtx
makeindex -s gind.ist rubikcube
makeindex -s gglo.ist -o rubikcube.gls rubikcube.glo
pdflatex rubikcube.dtx
pdflatex rubikcube.dtx
```

2.2 Placing the files

Place the files either in the local working directory, or where your system will find them. For a Linux system with a standard T_EX Directory Structure (TDS), then:

```
*.sty → /usr/local/texlive/texmf-local/tex/latex/rubik/
*.pdf → /usr/local/texlive/texmf-local/doc/rubik/
```

Finally, (depending on your system) update the T_EX file database. For example, on a Linux system one uses the `texhash` command.

2.3 Usage

Load the package by using the command `\usepackage{rubikcube}`. Note that the RUBIKCUBE package requires the TikZ package, and so always load TikZ before RUBIKCUBE as follows:

¹Since the documentation includes a complicated indexing system as well a PDF index and hyperref links (the package `hypdoc` is used), then several `pdflatex` runs are required. Prior to the first run it is a good idea to delete any relevant `.toc`, `.aux`, `.out` files.

```
\usepackage{tikz}
\usepackage{rubikcube,rubikrotation}
```

However, the RUBIKCUBE package does check for the presence of TikZ, and will load it if TikZ is not already loaded. While RUBIKCUBE is a stand-alone package, it is best to also load the complementary RUBIKROTATION package.

3 TikZ picture environment

For a basic introduction to the use of TikZ see the following manuals (from CTAN or from <http://altermundus.com/>).

- `pgfmanual.pdf`, version 3.0.1a (August 2015) (1161 pages)
- `pgfplot.pdf`, version 1.12.1 (2015) (504 pages)
- `tkz-base-screen.pdf`

An example of the TikZ picture environment for use with the RUBIKCUBE package is as follows:

```
\begin{tikzpicture}[scale=0.5]
...
\end{tikzpicture}%
```

If no scale is used (default scale = 1), then each of the small cubie sides will have a length of 1 cm.

A very useful feature of TikZ is that it automatically minimises the surrounding white-space, and consequently this is mostly quite sufficient. However, it is good practice to place a % symbol after the `\end{tikzpicture}` command *see above) to avoid additional white space (see Section 4.4).

3.1 \ShowCube command

`\ShowCube`
`\ShowCubeF`

When making side-by-side figures it can be very helpful to place each sub-figure inside a minipage. In this case, a useful approach is to first adjust the `tikzpicture` ‘scale’ parameter to obtain the appropriate size, and then adjust the minipage width as necessary (see Section 6.1). The `\ShowCube` macro (See Section 17.4) places one or more commands inside a `tikzpicture` environment and places all of these inside a minipage. It takes three arguments: the first is the minipage width (#1), second is the `tikzpicture` scale factor (#2), and third is a `\Draw..` command (#3).

USAGE: The following command would display a Rubik cube in a minipage of width 2cm using a `tikzpicture` scale factor of 0.5:

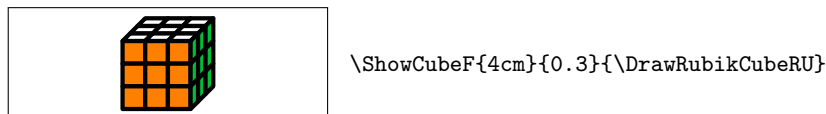
```
\ShowCube{2cm}{0.5}{\DrawRubikCubeRU}
```


For example, the following two sets of commands are equivalent (see Section 17.4 for the code); i.e., any commands which are valid in a `tikzpicture` environment may be used as the main argument for the `\ShowCube` command.

<pre> \RubikCubeSolved \begin{minipage}{2cm} \centering \begin{tikzpicture}[scale=0.5] \DrawRubikCubeRU \draw[->] (0.5,5) -- (0.5,4); \end{tikzpicture} \end{minipage} </pre>	}	<pre> \RubikCubeSolved \ShowCube{2cm}{0.5}{% \DrawRubikCubeRU \draw[->] (0.5,5) -- (0.5,4); } </pre>
--	---	---

The `\ShowCubeF` command is similar in all respects except that it places an fbox around the minipage in order to enable users to see the extent of any associated white space.

Unexpected spacing between two adjacent images, or between an image and adjacent text, is usually related to ‘hidden’ white-space associated with the image itself or excessive width of the associated `\minipage` (see also Section 4.4). Consequently, a temporary fbox around the minipage can be a useful aid when trying to visualise the full extent of the minipage (and its associated whitespace). Use the `\ShowCubeF` command for this, as follows:



Clearly either the minipage is too wide (4cm) or the `tikzpicture` scale factor is too small (0.3). Once the figure/code has been corrected, then the F in the `\ShowCubeF` command can be removed. Note that while the `\ShowCube` command centers the image inside the minipage, $\text{\LaTeX}$ positions the minipage in the `\textwidth`, and hence it is generally best to minimise the white-space as revealed by the `\ShowCubeF` command. The relationship between the required width of the minipage and the TikZ scale factor for the various Rubik cube images is detailed in Section 6.1.

3.2 \Draw error message

If a RUBIKCUBE `\Draw...` command is used *outside* a TikZ picture environment, then $\text{\LaTeX}$ issues an “Undefined control sequence” error message, indicating that it is trying to draw something using an undefined TikZ `\draw` command.

For example, if we use the RUBIKCUBE command `\DrawRubikFlat` without a surrounding TikZ picture environment then something similar to the following error message will be generated.

```

! Undefined control sequence.
\DrawFlatUp ... }{#1}\pgfmathsetmacro {\uy }{#2}\draw
[line join=round,...
1.56 \DrawRubikFlat

```

4 Command conventions

4.1 Commands and environments

Although the RUBIKCUBE package has been designed with TikZ in mind, it is important to appreciate that of all the various RUBIKCUBE commands only the Rubik `\Draw...` commands and TikZ commands actually have to be used inside a TikZ picture environment.

Indeed, using RUBIKCUBE commands which influence the Rubik colour state (configuration) outside the `tikzpicture`, `minipage` or `figure` environments can make for useful flexibility when a document is generating more than one figure or image. This is because the scope of any colours specified by commands inside these environments is constrained to be ‘local’ to that particular environment, and hence any change in the Rubik colour state brought about by such commands is not accessible globally (i.e., outside the environment) —see also Section 5 in the documentation of the RUBIKROTATION package.

Consequently users need to be mindful of the environments when drawing long sequences of rotations across several figures; for example, keeping `\RubikRotation` commands outside the environments keeps their effects global.

4.2 Capital letters

Each ‘word’ in a command (except the word ‘text’) starts with a capital letter. For example, `\DrawRubikCubeRU`, `\DrawCubieRU`. However, as with L^AT_EX, ‘text..’ commands start with a lowercase ‘t’; for example `\textCubieRU`. Letters for colours (R, O, Y, G, B, W, X) are always written in uppercase.

4.3 XYZ argument ordering

Many commands have an appended two (XY) or three (XYZ) ordered letter code which is used to for specifying some feature of the command; perhaps either face or cubie colours or a viewpoint direction.

The convention is that the letter codes are ordered in the XYZ order; i.e., the first code relates to an X-related parameter; for example L (Left) or R (Right); the second relates to a Y-related parameter; for example U (Up) or D (Down); the third (if required) relates to a Z-related parameter; for example F (Front) or B (Back).

EXAMPLE: `\DrawCubieRU{G}{Y}{O}` draws a cubie from the RightUp viewpoint. The sequence of colour codes for the three visible faces are XYZ ordered, and hence result in the cube having a Green Right face, Yellow Up face and Orange Front face.

4.4 Trailing % on the end of commands

It is important to include a trailing % on the end of RUBIKCUBE commands when used *outside* a TikZ picture environment, and also on the end of each

`\end{tikzpicture}` environment command. This is to prevent unwanted ‘space’ characters appearing in the graphics. In $\text{\TeX}$ every newline character is automatically converted to a white space—unless you have an empty line (Feuersänger 2015, § 3.2.3, page 20).

4.5 Cubies, cubicles, faces and facelets

The sub-cubes which make up the Rubik cube are known as ‘cubies’; the small coloured face of a cubie is known as a ‘facelet’. The cubies are named either according to the colours of their two or three facelets, or according to their physical position.

We distinguish three types of cubie: centre-cubies (single colour), edge-cubies (two colours) and corner-cubies (three colours). For example, the red/white edge-cubie is called the RW cubie, and the red/white/green corner-cubie is called the RWG cubie etc. Note that the colour of a particular face of a 3x3x3 Rubik cube is determined by the colour of its centre-cubie.

Similarly, the positions (known as ‘cubicles’) occupied by cubies are defined using either a two or three letter face code. For example the right edge position in the Up-layer is termed the Up/Right position, or just the UR position, and the corner joining the DOWN FRONT and RIGHT faces is the DFR position.

5 Colours

The RUBIKCUBE package uses seven colours which are defined as follows: red (R), orange (O), yellow (Y), green (G), blue (B), white (W), and grey (X). Now according to the following webpage²

<http://The-Rubiks-Cube.deviantart.com/journal/Using-Official-Rubik-s-Cube-Colors-268760351>

the official Rubik cube colours are defined as

```
.... colours which are red (PMS 200C*), green (PMS 347C*),
blue (PMS 293C*), orange (PMS 021C*), yellow (PMS 012C*)
and white.
.....
Pantone colors can not be accurately converted to RGB colors,
the colors the web runs on. But they can be approximated.
Through some research, I have found some estimations which
may help you which I have listed below. Remember, these are
just approximate RGB equivalents to the official Rubik's Cube
colors.

Red: 200C #C41E3A (www.perbang.dk/rgb/c41e3a/)
Green: 347C #009E60 (www.perbang.dk/rgb/009e60/)
Blue: 293C #0051BA (www.perbang.dk/rgb/0051ba/)
```

²We thank Peter Bartal for bringing this to our attention.

```

Orange: 021C "Pantone Orange" #FF5800 (www.perbang.dk/rgb/ff5800/)
Yellow: 012C "Pantone Yellow" #FFD500 (www.perbang.dk/rgb/ffd500/)
White: N/A #FFFFFF

```

```

Red      {HTML}{C41E3A}
green    {HTML}{009E60}
Blue     {HTML}{0051BA}
Yellow   {HTML}{FFD500}
Orange   {HTML}{FF5800}
White    {HTML}{FFFFFF}

```

However, we have optimised these prescribed colours very slightly for screen & print use (for example, the yellow was made very slightly brighter), and so the actual colours implemented by the RUBIKCUBE package are as follows (see Section 17.3):

```

\definecolor{R}{HTML}{C41E33}
\definecolor{G}{HTML}{00BE38}
\definecolor{B}{HTML}{0051BA}
\definecolor{Y}{HTML}{FFFF00}
\colorlet{O}{orange}
\colorlet{W}{white}
\colorlet{X}{black!30}%

```

Different colours can be allocated to the ROYGBWX letters (using the `\colorlet` command) as required. For example, the standard ‘red’ colour could be allocated to the letter R using the command

```
\colorlet{R}{red}
```

However, it is important to appreciate that the letter codes ROYGBWX are ‘hard-wired’ into many of the macros in the RUBIKCUBE package, so don’t change these.

5.1 Colour state of the cube

Initially, when L^AT_EX reads the file `rubikcube.sty` all facelets are allocated the code X, which can be regarded as a zero-colour state. Until a facelet is allocated one of the six Rubik colours it will be rendered as grey by a command which just draws the current colour state of the cube or a face (e.g., `\DrawFlatUpSide`).

It is important to appreciate that the various commands which typeset faces or facelets with colours differ in whether they derive the colours from the current internal colour ‘state’ (configuration) of the Rubik cube, or not.

The colour state of cubies in faces and slices can be allocated using `\RubikFace...` and `\RubikSlice...` (see Sections 8.2 and 8.5). The commands `\RubikCubeSolved` and `\ubikCubeGrey` allocate the colour state for the whole cube, and are useful starting points for subsequent rotations. Note that cubies will retain their colour allocation even if the cubies are moved by rotation commands, unless they are overwritten by a subsequent colour allocation command. To then visualise the cube one has to use a `\Draw...` command.

The RUBIKROTATION package keeps track of the Rubik state following rotations and sequences of rotations processed by its `\RubikRotation` command. The current colour state of the Rubik cube can be saved and written to a named file using its `\SaveRubikState` command; this file can then be `\input` when required.

Note that although some `\Draw...` commands (e.g., `\DrawRubikLayerFace...`) use colours as arguments, these commands really only ‘paint’ colours onto cubie positions (on the page, so to speak); i.e., these commands do not update the internal Rubik colour state, and hence these colours do not exist outside the particular `tikzpicture` environment the `\Draw...` command was used in.

6 Rubik cube coordinates

The coordinate origin of each view of the Rubik cube is located at the bottom-left corner of the FRONT face, as shown in Figure 1. Note also that the bottom left corner of the cube itself is at $(-1, -1)$, and hence the default height and width of the cube is 4cm.

Using the FRONT bottom-left corner as the origin is an important feature since knowing the location of the origin enables one to easily use any of the TikZ commands (e.g., `\draw` and `\node` commands) to superimpose lines, arrows and text etc. onto the Rubik cube (see Section 10).

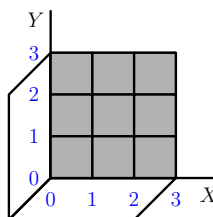


Figure 1: Origin of coordinates is at the bottom left corner of the grey FRONT face. The bottom left corner of the cube itself is at $(-1, -1)$, and hence the default height and width of the 3D-cube is 4cm.

6.1 Size of cube `\minipage`

Since the the default height and width of the 3D-cube is 4cm (see above), it follows that the width of the `\minipage` required for a cube in a `tikzpicture` environment can be easily calculated. For example, if the `tikzpicture` scale factor used is 0.5, then the minimum width of the required minipage for the `\DrawRubikCubeLD` view (shown above) is therefore $0.5 \times 4\text{cm} = 2\text{cm}$.

The default width of the semi-flat cube representation is 10cm ($= 3 + 3 + 1 + 3$), and that of the flat cube is 12cm ($= 3 + 3 + 3 + 3$). If in doubt check the extent of any horizontal white-space using an `fbox`, or the `\ShowCubeF` command.

7 Rotation commands

We use the standard Rubik cube notation of WCA (2012)—see article 12—and also the ‘s’ (Slice) and ‘a’ (anti-Slice) notation described in the ‘Notation and terminology’ section in the ‘Pretty patterns’ page on the website of Fridrich (see References).

It is recommended that commas are used to separate sequential Rubik moves or commands to avoid ambiguity, especially when using just lettercodes on their own. For example, in the following sequence the commas remove any ambiguity: **U,Lw2,U's',Da** (`\rr{U},\rr{Lw}2,\rr{Usp},\rr{Da}`).

7.1 Overview

The RUBIKCUBE notation comprises a range of commands for moves or rotations (e.g., **R**, **y**, **Bw**) and their equivalent hieroglyphs (e.g., $\boxed{\uparrow\uparrow}$, $\boxed{\mathbf{y}}$, $\boxed{\mathbf{Bw}}$), as well as commands for drawing 3x3x3 cubes and single cubies.

Note that there are a few rotation commands which do not have arrow hieroglyphs—their rotation is not visible from the FRONT face and hence cannot easily be rendered as an arrow hieroglyph. Consequently these rotations have a simple ‘letter’ hieroglyph in the form of the rotation-code in a square; for example $\boxed{\mathbf{Bw}}$, $\boxed{\mathbf{Sb}}$.

`\rr` The rotation-code of a rotation is typeset (as in text) using the rubik-rotation `\rr{<rotation-code>}` command: i.e., **R** is typeset using the command `\rr{R}`.
`\rrh` The hieroglyph of a rotation command is generated (in text) by using instead the command `\rrh{<rotation-code>}`. Thus the command `\rrh{R}` generates $\boxed{\uparrow\uparrow}$ which is the hieroglyph associated with **R**.

`\Rubik` A vertically combined rotation-code and its hieroglyph is generated using the command `\Rubik{<rotation-code>}`. For example, $\boxed{\uparrow\uparrow}$ is generated by the command `\Rubik{R}`, with the square hieroglyph sitting on the baseline. For some hieroglyphs (e.g., $\boxed{\mathbf{x}}$, $\boxed{\mathbf{y}}$, $\boxed{\mathbf{z}}$ denoting 90 degree axis rotations) the only difference between the `\rrh{}` and `\Rubik{}` forms is that the `\Rubik{}` form is elevated to sit on the baseline just like the other `\Rubik{}` hieroglyphs. For example `\rrh{yp}` generates $\boxed{\mathbf{y}'}$, while `\Rubik{yp}` generates $\boxed{\mathbf{y}'}$.

`\textRubik` A horizontally combined rotation-code and its hieroglyph (in sequence as in text) is generated using the command stem `\textRubik{<rotation-code>}`. For example, **R** $\boxed{\uparrow\uparrow}$ is typeset using the command `\textRubik{R}`. A list of all commands and their associated hieroglyphs is given in Section 7.8.

7.2 Face rotations

The six main faces of the cube are denoted as FRONT (towards the observer), BACK, LEFT, RIGHT, UP, DOWN. The uppercase initial letter of each face-name (**F**, **B**, **L**, **R**, **U**, **D**) denotes a clockwise 90-degree rotation of the face as shown in Figure 2. For example, **D** is generated by the ‘rubik rotation’ command `\rr{D}`.

An appended prime ‘*’* indicates an anticlockwise rotation; e.g., **F’**. This is sometimes written as **F**⁻¹. The ‘prime’ notation is achieved by appending a lowercase ‘p’ to the face rotation command. For example, **R’** is generated by `\rr{Rp}`.

Up
Dp
Lp
Rp
Fp
Bp

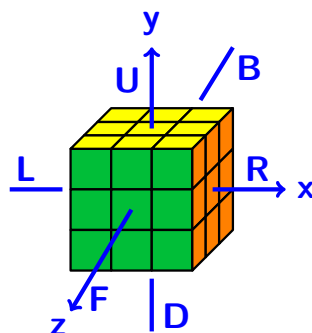


Figure 2:

7.3 Slice rotations

The Rubik cube (3x3x3) has three orthogonal so-called ‘inner’ slices, whose +ve rotation direction follows that of a named face. For example the inner slice rotation between the RIGHT and LEFT faces whose rotation direction follows the rotation **R** (rotation is isomorphic to **R**) is denoted as **Sr**, which is typeset using the command `\rr{Sr}`. Note that in these cases the trailing *r* in the command is lowercase.

Each of these slice rotations (S rotations) has a reversed (primed) p-form, the command for which is generated by appending the suffix ‘p’. For example the inner slice rotations **Sl’** (`\rr{Slp}`) and **Sr** (`\rr{Sr}`) are identical. The equivalence is more obvious when we see their respective hieroglyphs. For example, in this case **Sl’** (`\rr{Slp}`) $\equiv$ $\boxed{\uparrow\uparrow}$ (`\rrh{Slp}`), and **Sr** (`\rr{Sr}`) $\equiv$ $\boxed{\uparrow\uparrow}$ (`\rrh{Sr}`).

Sbp

MES slice notation

M An alternative and somewhat confusing (and hence is non-standard) slice notation
 E which is sometimes used is the following so-called MES notation, as used in the
 S Waterman algorithm (Treep and Waterman 1987).

Mp **M** (MIDDLE , between the LEFT and RIGHT faces; direction follows **L**),
 Ep **E** (EQUATOR , between the UP and DOWN faces; direction follows **D**),
 Sp **S** (STANDING , between the FRONT and BACK faces; direction follows **F**).

Each of these also has a reversed (prime) version, and a hieroglyph (see Section 7.8). The equivalent S notation (see above) is therefore as follows: **E** $\equiv$ **Sd**, **E'** $\equiv$ **Su**, **M** $\equiv$ **Sl**, **M'** $\equiv$ **Sr**, **S** $\equiv$ **Sf**, **S'** $\equiv$ **Sb**.

Singmaster slice notation

Us These are an alternative (but somewhat less intuitive) form of slice notation which
 Ds can be thought of as complementing the inner slice rotations. These were originally
 Ls described by Singmaster (Frey and Singmaster, 1982). See the link to ‘notation’
 Rs on the ‘Pretty patterns’ page of the Fridrich website.

Fs Each of these commands denotes a rotation of two opposite faces in the same
 Bs direction. For example, **Us**  $\equiv$ **U**  + **D'** , which is typeset as:
 $\text{\textRubik{Us}} \equiv \text{\textRubik{U}} + \text{\textRubik{Dp}}$, i.e., for **Us**
 both face-rotations are in the *same* direction as **U**.

Anti-slice notation

Ua Each of these commands denotes a rotation of two opposite faces in *opposite*
 Da directions. For example, **Ua**  $\equiv$ **U**  + **D** , which is typeset as:
 La $\text{\textRubik{Ua}} \equiv \text{\textRubik{U}} + \text{\textRubik{D}}$. See the link
 Ra to ‘notation’ on the ‘Pretty patterns’ page of the Fridrich website.
 Fa
 Ba

7.4 Wide rotations

Uw The clockwise *combined* rotation of an outer face AND its inner slice (officially
 Dw known as a ‘double outer slice’ rotation) is denoted by appending a lowercase **w**
 Lw (denoting ‘wide’) to a face rotation command. For example, a RIGHT double outer
 Rw slice rotation is denoted as **Rw**. Similarly, the prime ‘ version **Lw'** is generated by
 Fw $\text{\rr{Lwp}}$.

Bw The superscript ², or sometimes just an ordinary 2, indicates that the rotation
 is applied twice. For example **R**² or **R2** denote *two* successive 90 degree clockwise
 rotations of the RIGHT face. Clearly **R**³ is equivalent to **R'** etc.

7.5 Axis rotations

x Whole-cube clockwise rotations of 90-degrees about about the orthogonal axes
y centred on the RIGHT, UP, FRONT faces are denoted as **x**, **y**, **z** (the `\rr{}` forms)
z respectively (see Figure 2), with their hieroglyphs (the `\rrh{}` forms) being denoted as **[x]**, **[y]**, **[z]** in order to distinguish them from square layer-rotation hieroglyphs. Note that since **x**, **y**, **z** rotations are always expressed in lowercase, this practice is extended also to the commands.

An **x2** rotation (two **x** rotations one after the other, i.e., **[x]** **[x]**) denotes rotating the cube 180 degrees about its x axis so as to bring the DOWN face into the UP position.

An appended prime ' indicates an anticlockwise rotation; for example, **x'** (which is generated by appending a 'p' to the end of the command, i.e., `\rr{xp}`).

The `\Rubik{}` forms (and their prime 'p' versions) generate the same hieroglyphs as their `\rrh{}` versions, except that their spacing is similar to that associated with the 'square box' `\Rubik{}` hieroglyphs. Consequently when typesetting an axis command in a sequence of 'square-box' `\Rubik{}` commands, it is better to use the `\Rubik{}` form rather than the equivalent `\rrh{}` form (see the examples in Section 7.6). There are no `\textRubik{}` forms for the axis commands (since they are not necessary).

The u, d, l, r, f, b notation

u A commonly used alternative for the **x**, **y**, **z** notation (and endorsed by the WCA)
d uses these lowercase face letter to denote a 90 degree whole-cube rotation in the
l same directional sense as that of the standard face rotations.

r Thus **u** $\equiv$ **y**, **d** $\equiv$ **y'**, **l** $\equiv$ **x'**, **r** $\equiv$ **x**, **f** $\equiv$ **z**, **b** $\equiv$ **z'**,

f For example, **d** is generated by the command `\rr{d}`.

b Note that these rotations do not have prime ' versions since **u** is the opposite of **d**, **l** is the opposite of **r**, and **f** is the opposite of **b**.

As with the **[x]**, **[y]**, **[z]** forms (described above) there also equivalent `\rrh{}` and `\Rubik{}` forms. For example, **[d]** is generated by the command `\rrh{d}`.

7.6 Examples

R is generated by the 'rubik rotation' command `\rr{R}`

Fw is generated by the 'rubik rotation' command `\rr{Fw}`

L² is generated by `\rr{L}$^2$`

L2 is generated by `\rr{L}2`

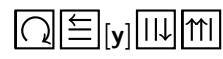
R' is generated by `\rr{Rp}`

Fw' is generated by `\rr{Fwp}`

x and **[y]** and **[z']** are generated by `\rr{x}` and `\rrh{y}` and `\Rubik{zp}`

f and **[b]** are generated by `\rr{f}` and `\rrh{b}`

UURR is generated by `\rr{U}\rr{U}\rr{R}\rr{R}`

 `\Rubik{F}\Rubik{U}\Rubik{y}\Rubik{Rp}\Rubik{Lwp}`
F U R' Lw'

F  **U**  `\textRubik{F}\ \textRubik{U}`

Commas can be important in avoiding ambiguity; for example

D,U2,F2,Ds2,B, `\rr{U}2,\rr{F}2,\rr{Ds}2,\rr{B},`

2, 2, 2, `\rrh{U}2,\,\,\rrh{F}2,\,\,\rrh{Ds}2,`

 [y]   `\rrh{F}\rrh{U}\rrh{y}\rrh{Rp}\rrh{Lwp}`

7.7 Backwards compatibility

Note that in keeping with ‘backwards compatibility’ all rotation commands (see below) can still be written without the usual curly braces `{}`. For example, the hieroglyph  (`\rrh{D}`) can also be generated using the command `\rrhD`.

7.8 Listing of all rotation commands

Note that all the commands presented here also have a `\Rubik{}` equivalent form which typesets both the hieroglyph and its lettercode in a vertical format, as shown in the ‘Examples’ section above. These have been omitted here owing to the difficulty of including this form easily in the following table.

Note also that some `\rrh{}` commands (eg the `\rrh{B}` command) show only the lettercode in a square box, e.g., . This is because these rotations do not have a ‘true’ visual representation as seen from the FRONT face, and hence can be somewhat ambiguous unless typeset with their associated lettercode.

U <code>\rr{U}</code>	 <code>\rrh{U}</code>	U  <code>\textRubik{U}</code>
U' <code>\rr{Up}</code>	 <code>\rrh{Up}</code>	U'  <code>\textRubik{Up}</code>
Uw <code>\rr{Uw}</code>	 <code>\rrh{Uw}</code>	Uw  <code>\textRubik{Uw}</code>
Uw' <code>\rr{Uwp}</code>	 <code>\rrh{Uwp}</code>	Uw'  <code>\textRubik{Uwp}</code>
Us <code>\rr{Us}</code>	 <code>\rrh{Us}</code>	Us  <code>\textRubik{Us}</code>
Us' <code>\rr{Usp}</code>	 <code>\rrh{Usp}</code>	Us'  <code>\textRubik{Usp}</code>
Ua <code>\rr{Ua}</code>	 <code>\rrh{Ua}</code>	Ua  <code>\textRubik{Ua}</code>
Ua' <code>\rr{Uap}</code>	 <code>\rrh{Uap}</code>	Ua'  <code>\textRubik{Uap}</code>

$\mathbf{D} \ \rr{D}$	$\boxed{\Rightarrow} \ \rrh{D}$	$\mathbf{D} \boxed{\Rightarrow} \ \text{textRubik}{D}$
$\mathbf{D}' \ \rr{Dp}$	$\boxed{\Leftarrow} \ \rrh{Dp}$	$\mathbf{D}' \boxed{\Leftarrow} \ \text{textRubik}{Dp}$
$\mathbf{Dw} \ \rr{Dw}$	$\boxed{\Rightarrow} \ \rrh{Dw}$	$\mathbf{Dw} \boxed{\Rightarrow} \ \text{textRubik}{Dw}$
$\mathbf{Dw}' \ \rr{Dwp}$	$\boxed{\Leftarrow} \ \rrh{Dwp}$	$\mathbf{Dw}' \boxed{\Leftarrow} \ \text{textRubik}{Dwp}$
$\mathbf{Ds} \ \rr{Ds}$	$\boxed{\Rightarrow} \ \rrh{Ds}$	$\mathbf{Ds} \boxed{\Rightarrow} \ \text{textRubik}{Ds}$
$\mathbf{Ds}' \ \rr{Dsp}$	$\boxed{\Leftarrow} \ \rrh{Dsp}$	$\mathbf{Ds}' \boxed{\Leftarrow} \ \text{textRubik}{Dsp}$
$\mathbf{Da} \ \rr{Da}$	$\boxed{\Rightarrow} \ \rrh{Da}$	$\mathbf{Da} \boxed{\Rightarrow} \ \text{textRubik}{Da}$
$\mathbf{Da}' \ \rr{Dap}$	$\boxed{\Leftarrow} \ \rrh{Dap}$	$\mathbf{Da}' \boxed{\Leftarrow} \ \text{textRubik}{Dap}$
$\mathbf{L} \ \rr{L}$	$\boxed{\Downarrow} \ \rrh{L}$	$\mathbf{L} \boxed{\Downarrow} \ \text{textRubik}{L}$
$\mathbf{L}' \ \rr{Lp}$	$\boxed{\Uparrow} \ \rrh{Lp}$	$\mathbf{L}' \boxed{\Uparrow} \ \text{textRubik}{Lp}$
$\mathbf{Lw} \ \rr{Lw}$	$\boxed{\Downarrow} \ \rrh{Lw}$	$\mathbf{Lw} \boxed{\Downarrow} \ \text{textRubik}{Lw}$
$\mathbf{Lw}' \ \rr{Lwp}$	$\boxed{\Uparrow} \ \rrh{Lwp}$	$\mathbf{Lw}' \boxed{\Uparrow} \ \text{textRubik}{Lwp}$
$\mathbf{Ls} \ \rr{Ls}$	$\boxed{\Downarrow} \ \rrh{Ls}$	$\mathbf{Ls} \boxed{\Downarrow} \ \text{textRubik}{Ls}$
$\mathbf{Ls}' \ \rr{Lsp}$	$\boxed{\Uparrow} \ \rrh{Lsp}$	$\mathbf{Ls}' \boxed{\Uparrow} \ \text{textRubik}{Lsp}$
$\mathbf{La} \ \rr{La}$	$\boxed{\Downarrow} \ \rrh{La}$	$\mathbf{La} \boxed{\Downarrow} \ \text{textRubik}{La}$
$\mathbf{La}' \ \rr{Lap}$	$\boxed{\Uparrow} \ \rrh{Lap}$	$\mathbf{La}' \boxed{\Uparrow} \ \text{textRubik}{Lap}$
$\mathbf{R} \ \rr{R}$	$\boxed{\Uparrow} \ \rrh{R}$	$\mathbf{R} \boxed{\Uparrow} \ \text{textRubik}{R}$
$\mathbf{R}' \ \rr{Rp}$	$\boxed{\Downarrow} \ \rrh{Rp}$	$\mathbf{R}' \boxed{\Downarrow} \ \text{textRubik}{Rp}$
$\mathbf{Rw} \ \rr{Rw}$	$\boxed{\Uparrow} \ \rrh{Rw}$	$\mathbf{Rw} \boxed{\Uparrow} \ \text{textRubik}{Rw}$
$\mathbf{Rw}' \ \rr{Rwp}$	$\boxed{\Downarrow} \ \rrh{Rwp}$	$\mathbf{Rw}' \boxed{\Downarrow} \ \text{textRubik}{Rwp}$
$\mathbf{Rs} \ \rr{Rs}$	$\boxed{\Uparrow} \ \rrh{Rs}$	$\mathbf{Rs} \boxed{\Uparrow} \ \text{textRubik}{Rs}$
$\mathbf{Rs}' \ \rr{Rsp}$	$\boxed{\Downarrow} \ \rrh{Rsp}$	$\mathbf{Rs}' \boxed{\Downarrow} \ \text{textRubik}{Rsp}$
$\mathbf{Ra} \ \rr{Ra}$	$\boxed{\Downarrow} \ \rrh{Ra}$	$\mathbf{Ra} \boxed{\Downarrow} \ \text{textRubik}{Ra}$

$\mathbf{Ra}' \rrap{Rap}$	$\boxed{\updownarrow} \rrh{Rap}$	$\mathbf{Ra}' \boxed{\updownarrow} \text{\texttt{\text{Rubik}}}\{Rap\}$
$\mathbf{F} \rrap{F}$	$\boxed{\curvearrowright} \rrh{F}$	$\mathbf{F} \boxed{\curvearrowright} \text{\texttt{\text{Rubik}}}\{F\}$
$\mathbf{F}' \rrap{Fp}$	$\boxed{\curvearrowleft} \rrh{Fp}$	$\mathbf{F}' \boxed{\curvearrowleft} \text{\texttt{\text{Rubik}}}\{Fp\}$
$\mathbf{Fw} \rrap{Fw}$	$\boxed{\odot} \rrh{Fw}$	$\mathbf{Fw} \boxed{\odot} \text{\texttt{\text{Rubik}}}\{Fw\}$
$\mathbf{Fw}' \rrap{Fwp}$	$\boxed{\ominus} \rrh{Fwp}$	$\mathbf{Fw}' \boxed{\ominus} \text{\texttt{\text{Rubik}}}\{Fwp\}$
$\mathbf{Fs} \rrap{Fs}$	$\boxed{\mathbf{F}_s} \rrh{Fs}$	$\boxed{\mathbf{F}_s} \text{\texttt{\text{Rubik}}}\{Fs\}$
$\mathbf{Fs}' \rrap{Fsp}$	$\boxed{\mathbf{F}_s'} \rrh{Fsp}$	$\boxed{\mathbf{F}_s'} \text{\texttt{\text{Rubik}}}\{Fsp\}$
$\mathbf{Fa} \rrap{Fa}$	$\boxed{\mathbf{F}_a} \rrh{Fa}$	$\boxed{\mathbf{F}_a} \text{\texttt{\text{Rubik}}}\{Fa\}$
$\mathbf{Fa}' \rrap{Fap}$	$\boxed{\mathbf{F}_a'} \rrh{Fap}$	$\boxed{\mathbf{F}_a'} \text{\texttt{\text{Rubik}}}\{Fap\}$
$\mathbf{B} \rrap{B}$	$\boxed{\mathbf{B}} \rrh{B}$	$\boxed{\mathbf{B}} \text{\texttt{\text{Rubik}}}\{B\}$
$\mathbf{B}' \rrap{Bp}$	$\boxed{\mathbf{B}'} \rrh{Bp}$	$\boxed{\mathbf{B}'} \text{\texttt{\text{Rubik}}}\{Bp\}$
$\mathbf{Bw} \rrap{Bw}$	$\boxed{\mathbf{B}_w} \rrh{Bw}$	$\boxed{\mathbf{B}_w} \text{\texttt{\text{Rubik}}}\{Bw\}$
$\mathbf{Bw}' \rrap{Bwp}$	$\boxed{\mathbf{B}_w'} \rrh{Bwp}$	$\boxed{\mathbf{B}_w'} \text{\texttt{\text{Rubik}}}\{Bwp\}$
$\mathbf{Bs} \rrap{Bs}$	$\boxed{\mathbf{B}_s} \rrh{Bs}$	$\boxed{\mathbf{B}_s} \text{\texttt{\text{Rubik}}}\{Bs\}$
$\mathbf{Bs}' \rrap{Bsp}$	$\boxed{\mathbf{B}_s'} \rrh{Bsp}$	$\boxed{\mathbf{B}_s'} \text{\texttt{\text{Rubik}}}\{Bsp\}$
$\mathbf{Ba} \rrap{Ba}$	$\boxed{\mathbf{B}_a} \rrh{Ba}$	$\boxed{\mathbf{B}_a} \text{\texttt{\text{Rubik}}}\{Ba\}$
$\mathbf{Ba}' \rrap{Bap}$	$\boxed{\mathbf{B}_a'} \rrh{Bap}$	$\boxed{\mathbf{B}_a'} \text{\texttt{\text{Rubik}}}\{Bap\}$
$\mathbf{Su} \rrap{Su}$	$\boxed{\Leftarrow} \rrh{Su}$	$\mathbf{Su} \boxed{\Leftarrow} \text{\texttt{\text{Rubik}}}\{Su\}$
$\mathbf{Su}' \rrap{Sup}$	$\boxed{\Rightarrow} \rrh{Sup}$	$\mathbf{Su}' \boxed{\Rightarrow} \text{\texttt{\text{Rubik}}}\{Sup\}$
$\mathbf{Sd} \rrap{Sd}$	$\boxed{\Rightarrow} \rrh{Sd}$	$\mathbf{Sd} \boxed{\Rightarrow} \text{\texttt{\text{Rubik}}}\{Sd\}$
$\mathbf{Sd}' \rrap{Sdp}$	$\boxed{\Leftarrow} \rrh{Sdp}$	$\mathbf{Sd}' \boxed{\Leftarrow} \text{\texttt{\text{Rubik}}}\{Sdp\}$
$\mathbf{Sl} \rrap{Sl}$	$\boxed{\updownarrow} \rrh{Sl}$	$\mathbf{Sl} \boxed{\updownarrow} \text{\texttt{\text{Rubik}}}\{Sl\}$
$\mathbf{Sl}' \rrap{Slp}$	$\boxed{\upuparrows} \rrh{Slp}$	$\mathbf{Sl}' \boxed{\upuparrows} \text{\texttt{\text{Rubik}}}\{Slp\}$
$\mathbf{Sr} \rrap{Sr}$	$\boxed{\upuparrows} \rrh{Sr}$	$\mathbf{Sr} \boxed{\upuparrows} \text{\texttt{\text{Rubik}}}\{Sr\}$

$\mathbf{S}' \rr{Srp}$	$\boxed{\Downarrow} \rrh{Srp}$	$\mathbf{S}' \boxed{\Downarrow} \text{\textRubik{Srp}}$
$\mathbf{Sf} \rr{Sf}$	$\boxed{\mathbf{Sf}} \rrh{Sf}$	$\boxed{\mathbf{Sf}} \text{\textRubik{Sf}}$
$\mathbf{Sf}' \rr{Sfp}$	$\boxed{\mathbf{Sf}'} \rrh{Sfp}$	$\boxed{\mathbf{Sf}'} \text{\textRubik{Sfp}}$
$\mathbf{Sb} \rr{Sb}$	$\boxed{\mathbf{Sb}} \rrh{Sb}$	$\boxed{\mathbf{Sb}} \text{\textRubik{Sb}}$
$\mathbf{Sb}' \rr{Sbp}$	$\boxed{\mathbf{Sb}'} \rrh{Sbp}$	$\boxed{\mathbf{Sb}'} \text{\textRubik{Sbp}}$
$\mathbf{E} \rr{E}$	$\boxed{\Rightarrow} \rrh{E}$	$\mathbf{E} \boxed{\Rightarrow} \text{\textRubik{E}}$
$\mathbf{E}' \rr{Ep}$	$\boxed{\Leftarrow} \rrh{Ep}$	$\mathbf{E}' \boxed{\Leftarrow} \text{\textRubik{Ep}}$
$\mathbf{M} \rr{M}$	$\boxed{\Downarrow} \rrh{M}$	$\mathbf{M} \boxed{\Downarrow} \text{\textRubik{M}}$
$\mathbf{M}' \rr{Mp}$	$\boxed{\Uparrow} \rrh{Mp}$	$\mathbf{M}' \boxed{\Uparrow} \text{\textRubik{Mp}}$
$\mathbf{S} \rr{S}$	$\boxed{\mathbf{S}} \rrh{S}$	$\boxed{\mathbf{S}} \text{\textRubik{S}}$
$\mathbf{S}' \rr{Sp}$	$\boxed{\mathbf{S}'} \rrh{Sp}$	$\boxed{\mathbf{S}'} \text{\textRubik{Sp}}$
$\mathbf{x} \rr{x}$	$\boxed{\mathbf{x}} \rrh{x}$	$\boxed{\mathbf{x}} \text{\textRubik{x}}$
$\mathbf{x}' \rr{xp}$	$\boxed{\mathbf{x}'} \rrh{xp}$	$\boxed{\mathbf{x}'} \text{\textRubik{xp}}$
$\mathbf{y} \rr{y}$	$\boxed{\mathbf{y}} \rrh{y}$	$\boxed{\mathbf{y}} \text{\textRubik{y}}$
$\mathbf{y}' \rr{yp}$	$\boxed{\mathbf{y}'} \rrh{yp}$	$\boxed{\mathbf{y}'} \text{\textRubik{yp}}$
$\mathbf{z} \rr{z}$	$\boxed{\mathbf{z}} \rrh{z}$	$\boxed{\mathbf{z}} \text{\textRubik{z}}$
$\mathbf{z}' \rr{zp}$	$\boxed{\mathbf{z}'} \rrh{zp}$	$\boxed{\mathbf{z}'} \text{\textRubik{zp}}$
$\mathbf{u} \rr{u}$	$\boxed{\mathbf{u}} \rrh{u}$	$\boxed{\mathbf{u}} \text{\textRubik{u}}$
$\mathbf{d} \rr{d}$	$\boxed{\mathbf{d}} \rrh{d}$	$\boxed{\mathbf{d}} \text{\textRubik{d}}$
$\mathbf{l} \rr{l}$	$\boxed{\mathbf{l}} \rrh{l}$	$\boxed{\mathbf{l}} \text{\textRubik{l}}$
$\mathbf{r} \rr{r}$	$\boxed{\mathbf{r}} \rrh{r}$	$\boxed{\mathbf{r}} \text{\textRubik{r}}$
$\mathbf{f} \rr{f}$	$\boxed{\mathbf{f}} \rrh{f}$	$\boxed{\mathbf{f}} \text{\textRubik{f}}$
$\mathbf{b} \rr{b}$	$\boxed{\mathbf{b}} \rrh{b}$	$\boxed{\mathbf{b}} \text{\textRubik{b}}$

8 Other commands

`\rubikcube` This command generates the logo RUBIKCUBE.

All RUBIKCUBE commands assume a 3x3x3 cube by default. There are three primary command categories: (a) `\Draw..` commands (which must always be used *inside* a TikZ picture environment), (b) parameter-allocation' commands—e.g., `\RubikCubeSolved`—which can be used either inside or outside a TikZ environment), and (c) commands which can be used in ordinary text (e.g., `\rr{}` rotation commands).

Since L^AT_EX commands have a maximum limit of only 9 parameters, it is necessary to use separate 'Face' and 'Slice' commands (see below) in order to accommodate all 27 visible colours of a 3D Rubik cube.

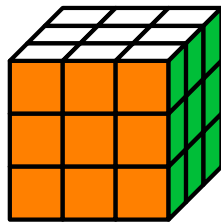
8.1 Draw commands

A `\Draw..` command typesets either a Rubik cube, cubie or a layer using parameters set or defined via previous parameter-allocation commands (eg face colours, dimensions etc). Furthermore, `\Draw..` commands can only be used *inside* a TikZ picture environment (see section 3.2).

`\DrawRubikCubeXY` This command draws Rubik cubes in one of four orientations as denoted by the following terminal XY viewing-direction codes: RU (RightUp), RD (RightDown), LU (LeftUp), LD (LeftDown). For example, the command

```
\DrawRubikCubeRU
```

will draw a Rubik cube as viewed from the RightUp direction (RU), as shown in the following figure.



```
\RubikCubeSolved
\begin{tikzpicture}[scale=0.7]
  \DrawRubikCubeRU
\end{tikzpicture}%
```

Note that these commands are equivalent to:

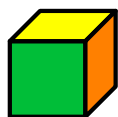
```
\RubikCubeSolved
\ShowCube{3cm}{0.7}{\DrawRubikCubeRU}
```

`\DrawCubieXYxyz` This command draws a single cubie in one of four orientations as denoted by the terminal XY viewing-direction codes. Since a single cubie has only three visible faces we can include colour parameters in `\DrawCubie` commands. Consequently `\DrawCubie` commands have the format

```
\DrawCubieXY{x}{y}{z}
```

where the XY pair denotes the viewing direction as before, and the xyz parameters denote the face colours associated with each of the three axes.

For example, the command `\DrawCubieRU{O}{Y}{G}` draws a single cubie as viewed from the RightUp direction, with face colours Orange (x-axis), Yellow (y-axis), Green (z-axis), as follows.



```
\begin{tikzpicture}[scale=1]
  \DrawCubieRU{0}{Y}{G}
\end{tikzpicture}%
```

Since the front face is a unit 1cm and the width of the side approx 1/3cm, and the scale factor =1, then the the minimum minipage width required for the cubie = $(1.33 \times 1) = 1.33\text{cm}$, and hence the above commands are equivalent to

```
\ShowCube{1.33cm}{1}{\DrawCubieRU{0}{Y}{G}}
```

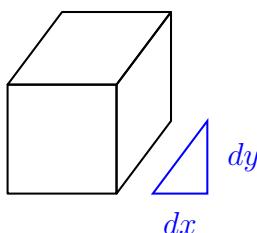


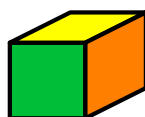
Figure 3: Cubie dy dx parameters

`\Cubiedy` Minor cubie configuration changes can be effected by adjusting the dy and dx values (> 0 ; no units) shown in Figure 3 via the two commands

`\Cubiedx`

```
\Cubiedy{}
\Cubiedx{}
```

as shown in the folowing example.



```
\begin{tikzpicture}[scale=1]
  \Cubiedy{0.4}
  \Cubiedx{0.8}
  \DrawCubieRU{0}{Y}{G}
\end{tikzpicture}%
```

Note that the FRONT face of the cubie is a unit square, and the graphic origin of the cubie image is at the bottom left corner of the FRONT face (see also the section on Arrows: Section 10). The default values of dy and dx are 0.4.

`\textCubieRU`
`\textCubieRD`
`\textCubieLU`
`\textCubieLD`

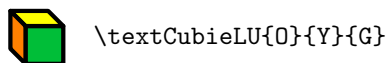
For convenience, there are also four (smaller) ‘text’ versions  of the four `\DrawCubie` commands for use in ordinary text, as follows:



`\textCubieRU{0}{Y}{G}`



`\textCubieRD{0}{Y}{G}`



`\textCubieLU{0}{Y}{G}`



`\textCubieLD{0}{Y}{G}`

Note that these `\textCubieXY` commands are not influenced by the `\Cubiedy`, `\Cubiedx` commands as their size is preset for text use.

8.1.1 `\draw error message`

See also section 3.2 regarding the error message associated with using a `\Draw...` command *outside* a TikZ picture environment.

8.2 Face commands

`\RubikFaceUp`
`\RubikFaceDown`
`\RubikFaceLeft`
`\RubikFaceRight`
`\RubikFaceFront`
`\RubikFaceBack`

These commands take nine colour arguments and allocate colours to the individual cubies of a Rubik cube face. The ordering is isomorphic to the sequence 1–9, i.e., numbering the small squares 1-3 (top row, left to right), 4-6 (middle row, left to right), 7-9 (bottom row, left to right), as follows:

#1	#2	#3
#4	#5	#6
#7	#8	#9

Conveniently, $\text{\LaTeX}$ allows the colour arguments to be separated by spaces (e.g., separated in groups of three), or even spread across several lines (e.g., in a square block to resemble a 9-face) in order to make the command more visually intuitive, as in the following examples.

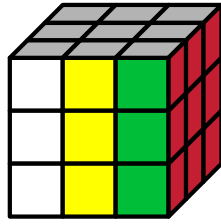
`\RubikFaceUp{G}{B}{G}    {G}{W}{O}    {G}{O}{G}`

`\RubikFaceFront{O}{W}{R}`
`{W}{W}{W}`
`{G}{W}{G}`

`\RubikFaceUpAll`
`\RubikFaceDownAll`
`\RubikFaceLeftAll`
`\RubikFaceRightAll`
`\RubikFaceFrontAll`
`\RubikFaceBackAll`

For convenience, each of these commands has an associated ‘All’ command which allocates the same colour to all the cubies on a 9-face (i.e., only a single colour argument is required).

If you want a particular face to be all grey, then one can either omit the particular ‘Face’ command (since the default colour is grey), or use a ‘Face’ command specifying the colour-code X; for example, `\RubikFaceUpAll{X}`. However, if you do use a Face command, then all of the command’s colour arguments must be allocated, as otherwise you will generate a ‘missing parameter’ error, and no colour will be allocated (i.e., you will see a black-hole). Use of these commands is shown in the following figure.



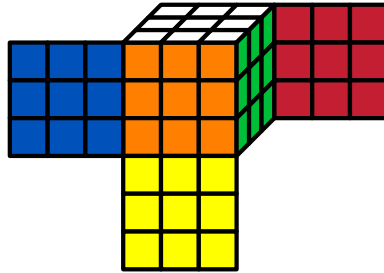
```
\RubikFaceUpAll{X}
\RubikFaceRightAll{R}
\RubikFaceFront{W}{Y}{G}
{W}{Y}{G}
{W}{Y}{G}
\ShowCube{3cm}{0.7}{\DrawRubikCubeRU}
```

8.3 RubikCubeSolved command

`\RubikCubeSolved` This command sets all the face colours to that of a standard ‘solved’ cube and is equivalent to the following set of face commands

```
\RubikFaceUpAll{W}%
\RubikFaceDownAll{Y}%
\RubikFaceLeftAll{B}%
\RubikFaceRightAll{G}%
\RubikFaceFrontAll{O}%
\RubikFaceBackAll{R}%
```

as shown in the following semi-flat image.



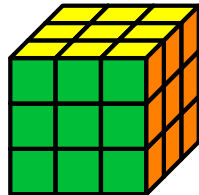
```
\RubikCubeSolved
\showcube{5cm}{0.5}{\DrawRubikCubeFlat}
```

Note that the width of the minipage above is set to 5cm. This is derived from the fact that the unscaled width of the semi-flat image is 10cm, and hence if the TikZ scale factor is to be 0.5 then the minimum minipage width = $10 \times 0.5 = 5\text{cm}$ (see Section 6 for details).

If other orientations of the solved cube are required, this can be easily achieved using the `\RubikRotation` command (from the `RubikRotation` package). For example, if one wants to show the solved cube upsidedown, then this format could be defined as follows (here we have used the rotations **x**, **x**, **y**, to invert the cube):

```
\newcommand{\CubeUpSideDown}{\RubikCubeSolved\RubikRotation{x2,y}}
```

This command would then generate the following:



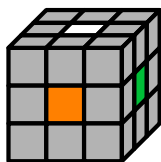
```
\CubeUpSideDown
\ShowCube{2.4cm}{0.6}\DrawRubikCubeRU}
```

Users can easily set their own alternative ‘solved’ face/colour configuration by ‘renewing’ the `\RubikCubeSolved` command as follows—remember to include the trailing % (note also that the colours ROYGBWX are currently hardwired so do not use a different set of uppercase letters).

```
\renewcommand{\RubikCubeSolved}{%
  \RubikFaceUpAll{..}%
  \RubikFaceDownAll{..}%
  \RubikFaceLeftAll{..}%
  \RubikFaceRightAll{..}%
  \RubikFaceFrontAll{..}%
  \RubikFaceBackAll{..}%
}
```

8.4 RubikCubeGrey command

`\RubikCubeGrey` This command generates a 3x3x3 cube with no colours allocated except for the central cubie of each face, which takes the same colour configuration as defined for the `\RubikCubeSolved` command. This command, which is useful starting point when wanting to describe the movement of particular cubies, generates the following cube:



```
\RubikCubeGrey
\ShowCube{3cm}{0.5}{\DrawRubikCubeRU}
```

Users can easily set their own alternative face/colour configuration by ‘renewing’ the `\RubikCubeGrey` command along the lines shown above (the code is in Section 17.6).

8.5 Slice commands

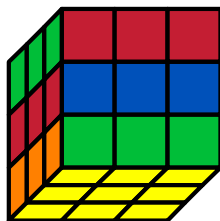
`\RubikSliceTopX` These three commands allocate the six visible cubie colours associated with a *horizontal* slice of a Rubik cube. There are three pairs of Slice commands; one pair (Left view & Right view) for each of the horizontal slices Top, Middle, Bottom. The six colour arguments associated with a given slice run in sequence from left to right irrespective of the viewpoint, e.g., #1 #2 #3 #4 #5 #6.

`\RubikSliceMiddleX`
`\RubikSliceBottomX`

Since the viewpoint of the Rubik cube (from the Right or from the Left) influences which face the colours are associated with, it is necessary to have the view (R or L) specified in the command name.

The format of the ‘slice’ command is shown in the following example. The Rubik cube is shown from the LeftDown (LD) view and consequently each of the ‘slice’ commands in this particular example ends in L, consistent with the final `\DrawRubikCubeLD` command.

Note that the two legacy ‘Equator’ versions (now replaced by ‘Middle’) are retained to allow backward compatibility.



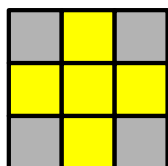
```
\RubikFaceDownAll{Y}
\RubikSliceTopL      {G}{G}{G} {R}{R}{R}
\RubikSliceMiddleL   {R}{R}{R} {B}{B}{B}
\RubikSliceBottomL   {O}{O}{O} {G}{G}{G}
\ShowCube{3cm}{0.7}{\DrawRubikCubeLD}
```

8.6 LayerFace & LayerSide commands

These commands are intended for drawing final layer configurations (i.e., typically using the yellow face in the UP position) with or without the associated side faces of the cubies of the top layer (see also the `\DrawFlatUpSide` command in Section 8.7)

8.6.1 LayerFace

`\DrawRubikLayerFace` This `LayerFace` command draws a simple Rubik cube 3x3 face and allocates colours to the 9 cubies. The command takes nine ordered colour arguments. Their use is illustrated in the following example, which shows a yellow cross configuration.



```
\ShowCube{2.1cm}{0.7}{%
  \DrawRubikLayerFace{X}{Y}{X}
                        {Y}{Y}{Y}
                        {X}{Y}{X}
}
```

8.6.2 \draw error message

See also section 3.2 regarding the error message associated with using a `\Draw...` command *outside* a TikZ picture environment.

8.6.3 LayerSide

`\DrawRubikLayerSideXYp` `LayerSide` commands draw the associated side colours of the top layer as small rectangular sidebars. The `LayerSide` commands adopt a three-letter XYp **position** notation where the XY pair define the location (X:[Left | Middle | Right]; Y:[Top | Middle | Bottom]) of a particular cubie in the layer face.

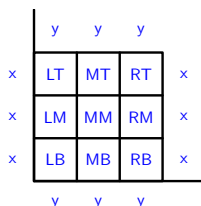


Figure 4: LayerSide rotation-codes

Since corner cubies have two side faces, the ‘p’ parameter (p:[x|y]) is required to denote the directional ‘position’ of the cubie side-face relative to the cubicle XY position (x indicates adjacent along the x-axis, and y indicates adjacent along the y-axis). Since edge cubies have only one side face, the ‘p’ parameter is optional (for consistency), since it is not strictly necessary.

Commands: Various different LayerSide commands are available: those for drawing a single colour side bar, and others for facilitating drawing all 12 side bars. For example, *either* of the following commands

```
\DrawRubikLayerSideLM{G}
\DrawRubikLayerSideLMx{G}
```

draws a single small vertical green rectangle  just to the left of the Left Middle (LM) square of the 9-face. The following commands draw all three side bars of a given side (Top, Bottom, Left, Right)

```
\DrawRubikLayerSideT{}{}{}
\DrawRubikLayerSideB{}{}{}
\DrawRubikLayerSideL{}{}{}
\DrawRubikLayerSideR{}{}{}

```

where the T and B forms require the colour parameters to be in left-right horizontal order (eg, left, middle, right), while the L and R forms require the colour parameters to be in top-down vertical order (eg, top, middle, bottom). Note that this means that the colour parameters of the L and R commands can (if required) then be positioned intuitively (vertically) as follows:

```
\DrawRubikLayerSideL{}
{}
{}

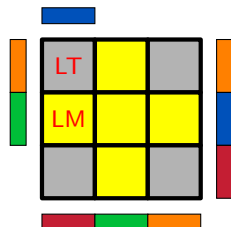
```

Extending this idea, the L and R forms are combined in the LR command, which takes six colour arguments ordered in left-right pairs,

```
\DrawRubikLayerSideLR{}{} {}{} {}{}

```

so that they can also be written vertically as left-right pairs. Use of these commands is shown in the following two examples.

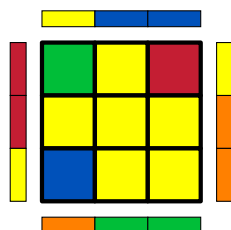


```
\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{X}{Y}{X}
                        {Y}{Y}{Y}
                        {X}{Y}{X}

  \DrawRubikLayerSideLTy{B}
  \DrawRubikLayerSideLTx{O}
  \DrawRubikLayerSideLM{G}

  \DrawRubikLayerSideR{O}{B}{R}
  \DrawRubikLayerSideB{R}{G}{O}

  \node (LT) at (0.5, 2.5)
    [red]{\small\textsf{LT}};
  \node (LM) at (0.5, 1.5)
    [red]{\small\textsf{LM}};
}
```



```
\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{G}{Y}{R}
                        {Y}{Y}{Y}
                        {B}{Y}{Y}

  \DrawRubikLayerSideT {Y}{B}{B}
  \DrawRubikLayerSideLR{R} {Y}
                        {R} {O}
                        {Y} {O}
  \DrawRubikLayerSideB {O}{G}{G}
}
```

`\DrawFlatUpSide`

IMPORTANT NOTE: If the colour configuration of the *whole* cube is already known to the system (i.e., it has been specified before, and (possibly) been manipulated using the `\RubikRotation...` command from RUBIKROTATION package), then the above figure could be drawn much more simply using just the single `\DrawFlatUpSide` command, as described in Section 8.7. In short, using the `rubikrotation` package to keep track of the Rubik cube configuration makes drawing these images considerably simpler.

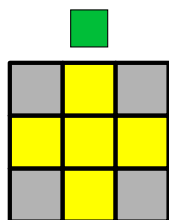
`\RubikSideBarWidth`
`\RubikSideBarLength`
`\RubikSideBarSep`

The default values (size) of the sidebars are as follows: width (0.3), length(1) and separation from the square face (0.3). Note that the default value of the length of a cubie side is 1. These sidebar values (decimal values ≥ 0 ; no units) can be changed from their default values using the three commands.

```
\RubikSideBarWidth{}
\RubikSideBarLength{}
\RubikSideBarSep{}
```

Values set in the document preamble will apply globally, while values set within a TikZ picture environment will apply only locally to that particular environment,

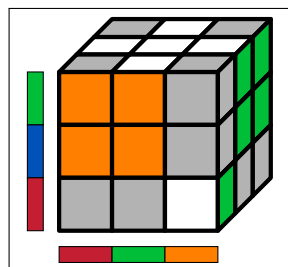
as shown in the following example where we have set both the sidebar width and length to 0.7.



```
\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{X}{Y}{X}
                        {Y}{Y}{Y}
                        {X}{Y}{X}
  \RubikSideBarWidth{0.7}
  \RubikSideBarLength{0.7}
  \DrawRubikLayerSideMTy{G}
}
```

Note also that changing the sidebar-width or sidebar-separation values may well also change the surrounding white-space (use `\fbox` to visualise this) and may therefore require some fine-tuning of the minipage width setting in order to optimise appearance.

Since the FRONT face drawn using the `\DrawRubikCube` command is identical with that drawn using the `\DrawLayerFace` command it follows that LayerSide commands can also be used in conjunction with the FRONT face drawn using `\DrawRubikCube` command, as shown in the following example. Note that in this example we have used the `\ShowCubeF` command as an exercise to implement the `fbox` and reveal the extent of the surrounding white space associated with a minipage width of 3.5cm ($= 5 \times 0.7$) —showing that a sidebar increases the image width by about 0.5 the width of a cubie.



```
\RubikFaceUp    {X}{W}{X}%
                {W}{W}{W}%
                {X}{W}{X}%

\RubikFaceFront{O}{O}{X}%
                {O}{O}{X}%
                {X}{X}{W}%

\RubikFaceRight{X}{G}{G}%
                {X}{G}{G}%
                {G}{X}{X}%

\ShowCubeF{3.5cm}{0.7}{%
  \DrawRubikCubeRU
  \DrawRubikLayerSideL{G}{B}{R}
  \DrawRubikLayerSideB{R}{G}{O}
}
```

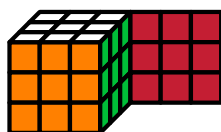
Note that since using a left or a right `\DrawRubikLayerSide` command in conjunction with a `\DrawRubikCube` command will necessarily increase the width of the image, one may also have to adjust the width of the associated minipage.

8.7 Flat commands

`\DrawFlatUp` `\DrawFlatDown` `\DrawFlatLeft` `\DrawFlatRight` `\DrawFlatFront` `\DrawFlatBack` These commands `\DrawFlat...{x}{y}` draw a ‘flat’ (square) representation of a specified face such that its bottom left corner is positioned at (x, y) . They are designed to supplement the `\DrawRubikCube...` commands and allow hidden faces to be represented. Each command (except `\DrawFlatFront`) takes two arguments, namely the X-coordinate and Y-coordinate of the bottom left corner of the face. This (x,y) pair allows the user to position the face.

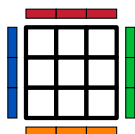
Note that the Y-argument set for the `\DrawFlatLeft` and `\DrawFlatRight` commands is not currently actioned (see Section 17.11), since both the LEFT and RIGHT faces as used by the `\DrawRubikCubeFlat` command—since this shows the RU view—requires only $Y=0$ (this (x,y) facility will be fully extended to the left and right forms in a later version). Note also that the `\DrawFlatFront` command currently takes no arguments, since by definition the bottom left corner of this face is always at $(0,0)$, and there seems to be no reason (just now) for this face to have the (x,y) facility.

In the following example we use the command `\DrawFlatBack{4}{1}` to append the BACK face to the side of a 3D cube. Note that since the coordinates of the bottom/back/right corner of the cube rendered by the command `\DrawRubikCubeRU` is $(4,1)$ (see Section 6), we can position the lower/left corner of the BACK face at this point using the command `\DrawFlatBack{4}{1}` as follows:



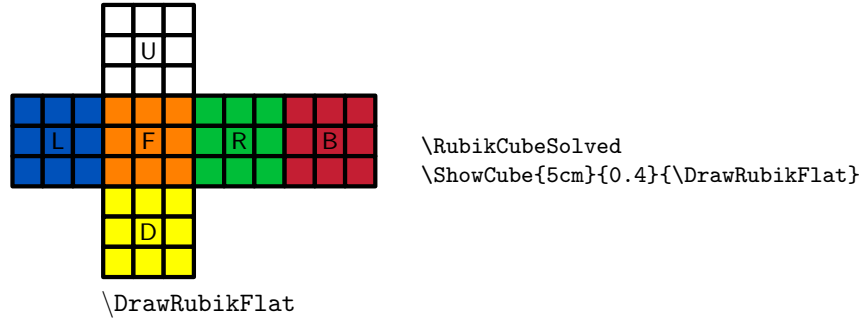
```
\RubikCubeSolved
\ShowCube{3cm}{0.4}{%
  \DrawRubikCubeRU
  \DrawFlatBack{4}{1}
}
```

`\DrawFlatUpSide` `\DrawFlatDownSide` `\DrawFlatLeftSide` `\DrawFlatRightSide` `\DrawFlatFrontSide` `\DrawFlatBackSide` These commands draw a face and all the associated side facelets. In the following example we use the `\DrawFlatUpSide` command to draw the UP face and all its side-bars of a cube having a ‘solved’ configuration.



```
\RubikCubeSolved
\ShowCube{1.6cm}{0.4}{%
  \DrawFlatUpSide
}
```

`\DrawRubikFlat` This command draws the completely flat format of the cube, as shown in the following example.

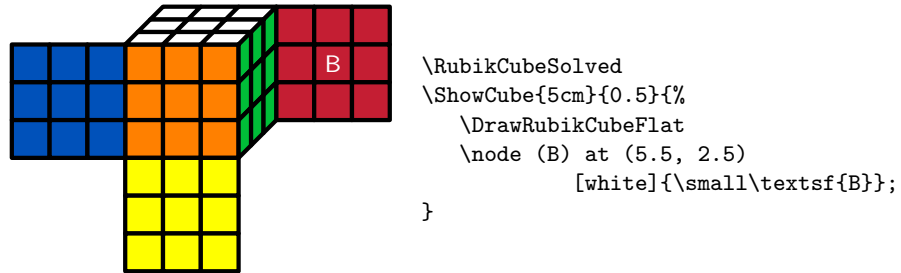


The addition of text (numbers or letters) in the faces is straightforward—the origin of the 1-unit grid is located at the bottom left corner of the front face (orange here). The letters were placed using the following TikZ code inside the TikZ picture environment.

```
\RubikCubeSolved
\ShowCube{5cm}{0.4}{%
  \DrawRubikFlat
  \node (U) at (1.5, 4.5) [black]{\small\textrm{U}};
  \node (D) at (1.5, -1.5) [black]{\small\textrm{D}};
  \node (L) at (-1.5, 1.5) [black]{\small\textrm{L}};
  \node (R) at (4.5, 1.5) [black]{\small\textrm{R}};
  \node (F) at (1.5, 1.5) [black]{\small\textrm{F}};
  \node (B) at (7.5, 1.5) [black]{\small\textrm{B}};
}
```

`\DrawRubikCubeFlat`

A useful ‘semi-flat’ alternative format, which uses the standard RU view of the cube and appends the three hidden sides (see Rokicki *et al.*, 2013), is generated by the command `\DrawRubikCubeFlat` as follows.



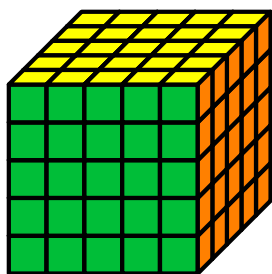
Note that even in this configuration it is straight-forward to write text on the graphic, since the width (on the page) of the green RIGHT face is exactly 1-unit, and the bottom right-hand corner of the green face is raised exactly 1-unit (see Figure 1). Consequently, since the origin of the grid is at the bottom left corner of the front face, the coordinates of the center of the red BACK face is (5.5, 2.5).

9 NCube (NxNxN)

`\DrawNCubeAll` An ‘NCube’ is a solved NxNxN cube drawn from the RU direction; (i.e., only shows faces UP, FRONT, RIGHT). The cubie colours of each face are All the same.

`\DrawNCubeAll{N}{Xcolour}{Ycolour}{Zcolour}`.

This command takes four ordered parameters (N, X, Y, Z)—the number (integer; $N > 0$) of cubies along an edge, followed by three face colours in XYZ order. Since the viewpoint is only from the RU direction, the three colour parameters are: X(Right), Y(Up), Z(Front).



`\ShowCube{3.5cm}{0.5}{\DrawNCubeAll{5}{0}{Y}{G}}`

9.0.1 \draw error message

See also section 3.2 regarding the error message associated with using a `\Draw...` command *outside* a TikZ picture environment.

10 Arrows

The RUBIKCUBE package does not offer any special commands for drawing arrows since it is straightforward just to include the appropriate TikZ ‘draw’ commands in the `tikzpicture` environment.

In order to facilitate using the standard TikZ ‘draw’ commands both the `RubikCubeFaceFront` and `LayerFace` commands have the coordinate origin at the bottom left corner, and draw ‘faces’ consisting of 9 unit-squares in a 3x3 grid, as shown in Figure 5. Consequently the start and finish coordinates for any arrow or line are easy to determine.

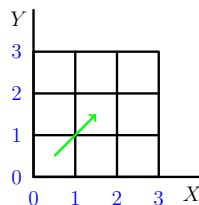
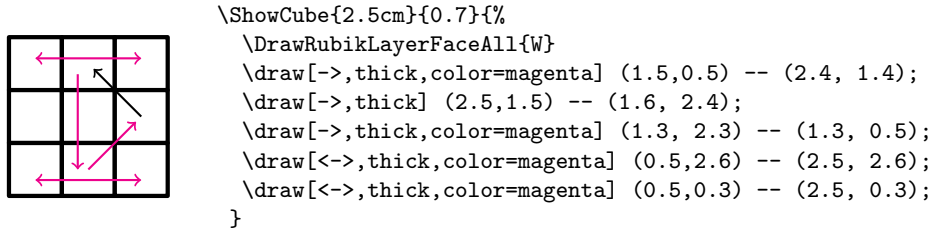


Figure 5: `RubikCubeFaceFront` and `RubikLayerFace` coordinates

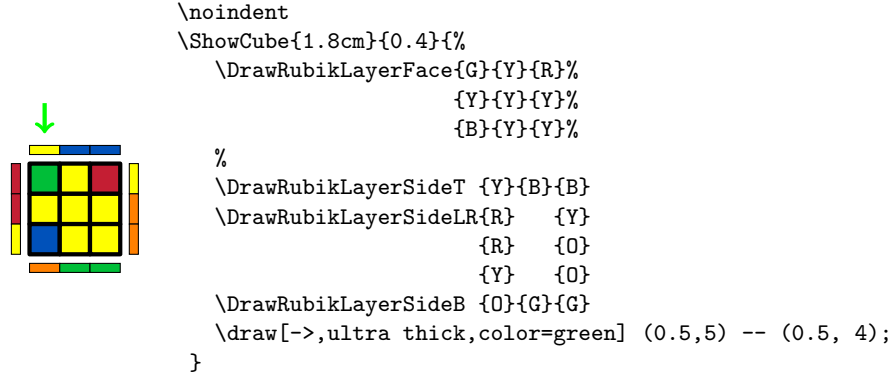
For example, in Figure 5 we have drawn a green arrow from the centre of cubie LB (0.5,0.5) to the centre of cubie MM³ (1.5,1.5). To do this we just include the following TikZ command in the `tikzpicture` environment.

```
\draw[->,color=green] (0.5,0.5) -- (1.5, 1.5);
```

The following example shows the cubie changes in the UP face generated by the rotation sequence **FRUR'U'F'**. The magenta arrows indicate movement *with* cubie rotations, while the black arrow indicates movement *without* rotation. This example also highlights the fact that when there are several arrows, the start and end positions often need to be offset slightly away from cubie centres.

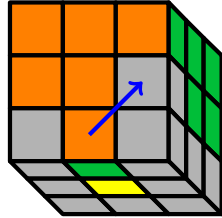


Since the coordinates shown in Figure 5 extend outwards in all directions, they can also be used as a guide for drawing arrows (or other structures) outside this 3x3 'face' square. This approach is shown in the following example, where we have changed the `tikzpicture` scale factor to 0.4 in order to generate a small figure in order to facilitate placing the figure and the code side-by-side.



The following example shows an arrow on the Rubik cube. The origin of coordinates is at the bottom left corner of the FRONT face (see Section 6).

³The code MM stands for x=Middle, y=Middle; see also Figure 4 on Rubik face-notation



```

\RubikFaceFront{0}{0}{0}
              {0}{0}{X}
              {X}{0}{X}

\RubikFaceRight{G}{G}{G}
              {X}{G}{G}
              {X}{X}{X}

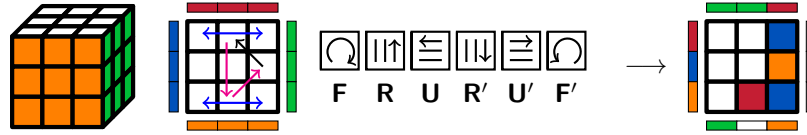
\RubikFaceDown {X}{G}{X}
              {X}{Y}{X}
              {X}{X}{X}

\ShowCube{3cm}{0.7}{%
  \DrawRubikCubeRD
  \draw[ultra thick,->,color=blue]
      (1.5,0.5) -- (2.5, 1.5);
}

```

11 Final example

We now present, as a final example, the code used to draw the front page figure⁴. This code uses both the RUBIKCUBE and RUBIKROTATION packages, and therefore needs to be run using the L^AT_EX `--shell-escape` command-line switch, as described in the RUBIKROTATION package.



```

\hfil
\RubikCubeSolved
\ShowCube{2cm}{0.4}{\DrawRubikCubeRU}
\ShowCube{2cm}{0.4}{%
  \DrawFlatUpSide
  \draw[thick,->,color=magenta] (1.5,0.5) -- (2.4, 1.4);
  \draw[thick,->] (2.5,1.5) -- (1.6, 2.4);
  \draw[thick,->,color=magenta] (1.3, 2.3) -- (1.3, 0.5);
  \draw[thick,<->, color=blue] (0.5,2.6) -- (2.5, 2.6);
  \draw[thick,<->, color=blue] (0.5,0.3) -- (2.5, 0.3);
}
\Rubik{F}\Rubik{R}\Rubik{U}\Rubik{Rp}\Rubik{Up}\Rubik{Fp}%
\ \ \ $\longrightarrow$
\RubikRotation{F,R,U,Rp,Up,Fp}
\ShowCubeF{2cm}{0.4}{\DrawFlatUpSide}
\hfil

```

⁴This is a sequence of order 6 used to generate the ‘cross’ configuration when solving the cube. Doing it on a ‘solved’ cube allows you to see how the three edge cubies move, and either flip (magenta arrows) or do not flip (black arrow).

11.1 Without using `\RubikRotation`..

If you really need to draw the above figure *without* using the RUBIKROTATION package (as we had to in order to write this particular document) then you would need to replace the commands

```
\RubikRotation{F,R,U,Rp,Up,Fp}  
\ShowCubeF{2cm}{0.4}{\DrawFlatUpSide}
```

with the following set of `\DrawRubikLayer`... commands.

```
\ShowCube{2cm}{0.4}{%  
  \DrawRubikLayerFace{W}{W}{B}  
    {W}{W}{O}  
    {W}{R}{B}  
  \DrawRubikLayerSideT {G}{G}{R}  
  \DrawRubikLayerSideLR{R} {W}  
    {B} {W}  
    {O} {W}  
  \DrawRubikLayerSideB {G}{W}{O}  
}
```

12 Known issues & shortcomings

Please contact the authors regarding any ideas, errors or shortcomings etc.

- The rotation hieroglyphs are optimised for a 10pt font, and do not scale with document font size. However, they do seem to work reasonably well with both 11pt and 12pt fonts. Any suggestions are welcome.
- The sidebars cannot be arbitrarily positioned.

13 Acknowledgements

We would like to thank Peter Bartal and Peter Grill for useful ideas and suggestions. We have built on some of their ideas and have acknowledged these instances in the documentation. We would also like to thank Christian Tellechea for the `\@join{}{}` command.

14 Future supporting packages

Since Rubik-type cubes currently exist in a variety of sizes (from 2x2x2 to 11x11x11) it is possible that similar packages dealing with cubes of other sizes may be made in the future. Supporting tools may also be made using various programming languages, e.g., Lua etc. Consequently the naming of such packages and tools, and even the associated CTAN directories, needs to be given some thought in order to prevent possible confusion.

In the event of new packages being made, we suggest that a CTAN directory structure along the following lines might be appropriate.

$$\text{RUBIK} \left\{ \begin{array}{l} \text{rubiktools} \\ \text{rubik2x} \\ \text{rubik3x} \\ \dots \\ \text{rubik11x} \end{array} \right.$$

15 History

- Version 3.0 (September 2015)
 - All rotation commands can now use the rotation-code as an argument; for example, the rotation **D** can now be typeset using the command `\rr{D}` etc (see Section 7). The new rotation commands are:

```
\rr{<rotation-code>}
\rrh{<rotation-code>}
\Rubik{<rotation-code>}
\textRubik{<rotation-code>}
```

The original rotation command formats (e.g., `\rrD`) are still supported for backwards compatibility.

- `\ShowCube` and `\ShowCubeF` are new commands for displaying a cube inside a minipage (see Sections 3.1 and 17.4).

- `\RubikCubeGrey` is a new command for setting up a ‘starter cube’ for which the only allocated colours are those for the centre cubies (see Section 8.4). The colour configuration matches that of the `\RubikCubeSolved`.

- Version 2.2 (January 2015)
 - Fixed typos and minor errors in the documentation.
 - Added the following commands to facilitate typesetting a face, as described in Section 8.7.

```
\DrawFlatUp
\DrawFlatDown
\DrawFlatLeft
\DrawFlatRight
\DrawFlatFront
\DrawFlatBack
\DrawFlatUpSide
\DrawFlatDownSide
\DrawFlatLeftSide
\DrawFlatRightSide
\DrawFlatFrontSide
\DrawFlatBackSide
```

—Changed ‘Equator’ $\rightarrow$ ‘Middle’ in all `\DrawLayer..` commands (for consistency). Hence ‘E’ $\rightarrow$ ‘M’ in all Flat commands and Slice commands. Note although former use of ‘Equator’ is retained for backward compatibility (for the moment) it is now deprecated.

—Fixed a conflict with the $\text{\TeX}$ `\sb` command as used by the `url` package which resulted in reference chaos when the `url` package was used with the RUBIKCUBE package (internalised `\sb` to `\@sb`). Also internalised for convenience `\sd` to `\@sd`; `\sh` to `\@sh`; `\sc` to `\@sc`; `\sq` to `\@sq`.

- Version 2.0 (February 5, 2014)

—First release.

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17 The code (rubikcube.sty)

The conventions we adopt regarding capital letters and the XYZ argument ordering are detailed in Section 4.

Note that it is important in a graphics package to use a trailing % on the end of lines which break before the terminal curly bracket of a newcommand. This is to prevent accumulating spurious spaces which may otherwise appear in figures and diagrams as a strange or unexpected horizontal shift or whitespace.

17.1 Package heading

```

1 (*rubikcube)
2 \def\RCfileversion{3.0}%
3 \def\RCfiledate{2015/09/25}%
4 \NeedsTeXFormat{LaTeX2e}
5 \ProvidesPackage{rubikcube}[\RCfiledate\space (v\RCfileversion)]

```

The package requires TikZ—so we load it if not already loaded.

```

6 \ifpackageloaded{tikz}{}{%
7   \typeout{---rubikcube requires the TikZ package.}%
8   \RequirePackage{tikz}}%

```

\rubikcube First we create a suitable logo

```

9 \newcommand{\rubikcube}{\textsc{rubikcube}}%
10 \newcommand{\Rubikcube}{\textsc{Rubikcube}}%

```

17.2 Some useful internal commands

\@rr \@rrp \@rrw \@rrwp \@rrs \@rrsp \@rra \@rrap \@xyzh \@xyzhp \@xyzRubik \@xyzRubikp \@SquareLetter \@hRubik	Internal commands. These are used to generate the prime, w, w-prime, s, s-prime, a, a-prime rotation commands. The \@xyz.. commands are used to generate the x,y,z,u,d,l,r,f,b, and their prime rotation commands. The \@SquareLetter command is used to form the separate square hieroglyph form used for rotations with no visible representation from the front (eg B., Fs, Fsp, Fa, Fap, S, Sp, Sf, Sfp, Sb, Sbp). The \@hRubik is the vertical shift used to raise the box carrying the rotation rotation-code in \Rubik.. commands not visible from the front. The idea is that by using these internal tools we will be able to more easily standardise the size and position of all the various glyphs. However, these internal tools are currently only partially implemented (= work in progress). <pre> 11 \newcommand{\@rr}[1]{\textbf{\textsf{#1}}} 12 \newcommand{\@rrp}[1]{\textbf{\textsf{#1}}\$^{\prime}\$} 13 \newcommand{\@rrw}[1]{\textbf{\textsf{#1}\footnotesize{w}}}} 14 \newcommand{\@rrwp}[1]{\textbf{\textsf{#1}\footnotesize{w}}\$^{\prime}\$} 15 \newcommand{\@rrs}[1]{\textbf{\textsf{#1}\footnotesize{s}}}} 16 \newcommand{\@rrsp}[1]{\textbf{\textsf{#1}\footnotesize{s}}\$^{\prime}\$} 17 \newcommand{\@rra}[1]{\textbf{\textsf{#1}\footnotesize{a}}}} 18 \newcommand{\@rrap}[1]{\textbf{\textsf{#1}\footnotesize{a}}\$^{\prime}\$} 19 \newcommand{\@xyzh}[1]{\textbf{[\textsf{#1}]}\,,} 20 \newcommand{\@xyzhp}[1]{\textbf{[\textsf{#1}}\$^{\prime}\$]\,,} 21 \newcommand{\@xyzRubik}[1]{\raisebox{3.45pt}{\textbf{[\textsf{#1}]}}} </pre>
---	---


```

22 \newcommand{\@xyzRubikp}[1]{\raisebox{3.45pt}{\textbf{[\textsf{#1}]$^\prime$}}}}
23 \newcommand{\@SquareLetter}[1]{\setlength\fbboxsep{2.5pt}\fbboxrule=0.8pt%
24   \fbbox{\rule[-1pt]{0pt}{8.5pt}\raisebox{-0.5pt}{#1}}}
25 \newlength\@hRubik%
26 \setlength\@hRubik{0.185cm}%

```

`\@join` We also require a macro for joining two strings so we can convert a rotation-code, say U, into a macro which typesets it in some form, say `\rrhU`. The following `\@join{}{}` command is by Christian Tellechea.

Usage: `\@join{<command-stem>}{<rotation-code>}`. For example, to create the command `\rrhU` we would write `\@join{\rrh}{U}`, and hence the command `\rrh{U}` is equivalent to `\rrhU` (see Section 17.16.2).

Since this macro is also useful for processing rotation-codes in a list, which may also include macros, it is important that #2 is not detokenized.

```

27 \newcommand*\@join[2]{%
28   \csname\expandafter\@gobble\string#1#2\endcsname}

```

17.3 Colours

These colour allocations were initially defined by Peter Bartal (2011). We have modified only the colour grey, which is now defined as black!30.

```

29 \definecolor{R}{HTML}{C41E33}%
30 \definecolor{G}{HTML}{00BE38}%
31 \definecolor{B}{HTML}{0051BA}%
32 \definecolor{Y}{HTML}{FFFF00}%
33 \colorlet{X}{black!30}% grey
34 \colorlet{O}{orange}%
35 \colorlet{W}{white}%

```

17.4 ShowCube command

`\ShowCube` The macro `\ShowCube{<minipage width>}{<TikZ scale factor>}{<Draw.. cmd>}` displays the cube inside a minipage, so that we can easily tailor the minipage width (#1) and also the TikZ scale factor (#2). The `\ShowCubeF` command places an fbox around the minipage so users can see the extent of any white space.

USAGE: `\ShowCube{2cm}{0.5}{\DrawRubikCubeRU}`

```

36 \newcommand{\ShowCube}[3]{%
37   \begin{minipage}{#1}%
38   \centering%
39   \begin{tikzpicture}[scale=#2]%
40     #3%
41   \end{tikzpicture}%
42   \end{minipage}%
43 }
44 \newcommand{\ShowCubeF}[3]{%
45   \fbbox{%
46     \begin{minipage}{#1}%

```

```

47 \centering%
48 \begin{tikzpicture}[scale=#2]%
49 #3%
50 \end{tikzpicture}%
51 \end{minipage}%
52 }}

```

17.5 Face commands

Cube face notation = U, D, L, R, F, B (Singmaster)

Cubie-square notation = t, m, b, l, m, r = top, middle, bottom, left, middle, right. We use t,b for cubie-squares (facelets) to avoid confusion with cube Face notation. We number the cubie-squares on a face 1–9 reading from left-to-right, starting top-left, ending bottom-right, as follows (see also Figure 4):

```

top row    (1,2,3) = tl, tm, tr
middle row (4,5,6) = ml, mm, mr
bottom row (7,8,9) = bl, bm, br

```

<pre> \RubikFaceUp \RubikFaceDown \RubikFaceLeft \RubikFaceRight \RubikFaceFront \RubikFaceBack </pre>	These 5 commands allocate a colour to each of the 9 cubie-squares in the specified face (Up, Down, Left, Right, Front, Back). Each command takes 9 arguments (colour codes) in the order 1–9 as specified above. EXAMPLE: <code>\RubikFaceUp{R}{O}{Y} {G}{B}{W} {X}{R}{G}</code> Each of the 9 <code>\def{}</code> commands below allocates one colour to a specific cubie-square (facelet), using a simple three-letter encoding. Each letter is an initial letter of the words Up, Down, Left, Right, Front, Back, left, middle, right, top, middle, bottom.
--	---

For example, in the command `\Urt{#1}` the U stands for the Up face of the cube, while the `rt` stands for the “right-top” facelet on this face. Note that the order of the two lowercase letters (in this case `rt`) are always written in the x, y order; i.e., the first of the two lowercase letters relates to the x direction (either left, middle, or right), while the second lowercase letter relates to the y direction (either top, middle, or bottom)—this rule makes it easy to remember the order.

```

53 \newcommand{\RubikFaceUp}[9]{%
54 \def\Ult{#1}\def\Umt{#2}\def\Urt{#3}%
55 \def\Ulm{#4}\def\Umm{#5}\def\Urm{#6}%
56 \def\Ulb{#7}\def\Umb{#8}\def\Urb{#9}%
57 }
58 \newcommand{\RubikFaceFront}[9]{%
59 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
60 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
61 \def\Flb{#7}\def\Fmb{#8}\def\Frb{#9}%
62 }
63 \newcommand{\RubikFaceRight}[9]{%
64 \def\Rlt{#1}\def\Rmt{#2}\def\Rrt{#3}%
65 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
66 \def\Rlb{#7}\def\Rmb{#8}\def\Rrb{#9}%
67 }

```

```

68 \newcommand{\RubikFaceDown}[9]{%
69 \def\Dlt{#1}\def\Dmt{#2}\def\Drt{#3}%
70 \def\Dlm{#4}\def\Dmm{#5}\def\Dr{#6}%
71 \def\Dllb{#7}\def\Dllm{#8}\def\Dllr{#9}%
72 }
73 \newcommand{\RubikFaceLeft}[9]{%
74 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
75 \def\Llm{#4}\def\Lmm{#5}\def\Lrm{#6}%
76 \def\Llb{#7}\def\Lmb{#8}\def\Lrb{#9}%
77 }
78 \newcommand{\RubikFaceBack}[9]{%
79 \def\Blt{#1}\def\Bmt{#2}\def\Brt{#3}%
80 \def\Blm{#4}\def\Bmm{#5}\def\Brm{#6}%
81 \def\Blb{#7}\def\Bmb{#8}\def\Brb{#9}%
82 }

```

\RubikFaceUpAll These 5 commands allocate the same colour to all 9 cubiesquares in the specified face (Up, Down, Left, Right, Front). Each command therefore takes only 1 argument (one of the colour codes).
\RubikFaceDownAll
\RubikFaceLeftAll
\RubikFaceRightAll For example, \RubikFaceUpAll{R}
\RubikFaceFrontAll
\RubikFaceBackAll

```

83 \newcommand{\RubikFaceUpAll}[1]{%
84 \def\Ult{#1}\def\Umt{#1}\def\Urt{#1}%
85 \def\Ulm{#1}\def\Umm{#1}\def\Urm{#1}%
86 \def\Ulb{#1}\def\Umb{#1}\def\Urb{#1}%
87 }
88 \newcommand{\RubikFaceFrontAll}[1]{%
89 \def\Flt{#1}\def\Fmt{#1}\def\Frt{#1}%
90 \def\Flm{#1}\def\Fmm{#1}\def\Frm{#1}%
91 \def\Flb{#1}\def\Fmb{#1}\def\Frb{#1}%
92 }
93 \newcommand{\RubikFaceRightAll}[1]{%
94 \def\Rlt{#1}\def\Rmt{#1}\def\Rrt{#1}%
95 \def\Rlm{#1}\def\Rmm{#1}\def\Rrm{#1}%
96 \def\Rlb{#1}\def\Rmb{#1}\def\Rrb{#1}%
97 }
98 \newcommand{\RubikFaceLeftAll}[1]{%
99 \def\Llt{#1}\def\Lmt{#1}\def\Lrt{#1}%
100 \def\Llm{#1}\def\Lmm{#1}\def\Lrm{#1}%
101 \def\Llb{#1}\def\Lmb{#1}\def\Lrb{#1}%
102 }
103 \newcommand{\RubikFaceDownAll}[1]{%
104 \def\Dllt{#1}\def\Dllm{#1}\def\Dllr{#1}%
105 \def\Dllb{#1}\def\Dllm{#1}\def\Dllr{#1}%
106 \def\Dllb{#1}\def\Dllm{#1}\def\Dllr{#1}%
107 }
108 \newcommand{\RubikFaceBackAll}[1]{%
109 \def\Blt{#1}\def\Bmt{#1}\def\Brt{#1}%
110 \def\Blm{#1}\def\Bmm{#1}\def\Brm{#1}%
111 \def\Blb{#1}\def\Bmb{#1}\def\Brb{#1}%

```

```
112 }
```

We now use these commands to initialise all visible faces to default colour grey (X)

```
113 \RubikFaceUpAll{X}%
114 \RubikFaceDownAll{X}%
115 \RubikFaceLeftAll{X}%
116 \RubikFaceRightAll{X}%
117 \RubikFaceFrontAll{X}%
118 \RubikFaceBackAll{X}%
```

17.6 RubikCubeGrey command

`\RubikCubeGrey` This command sets the face/colour configuration (state) of a 3x3x3 Rubik cube with no colours allocated except for the central cubie of each face. These central colours match those defined for the `RubikCubeSolved` command.

```
119 \newcommand{\RubikCubeGrey}{%
120 \RubikFaceUp {X}{X}{X}{X}{W}{X}{X}{X}{X}%
121 \RubikFaceDown {X}{X}{X}{X}{Y}{X}{X}{X}{X}%
122 \RubikFaceLeft {X}{X}{X}{X}{B}{X}{X}{X}{X}%
123 \RubikFaceRight{X}{X}{X}{X}{G}{X}{X}{X}{X}%
124 \RubikFaceFront{X}{X}{X}{X}{O}{X}{X}{X}{X}%
125 \RubikFaceBack {X}{X}{X}{X}{R}{X}{X}{X}{X}%
126 }
```

17.7 RubikCubeSolved command

`\RubikCubeSolved` This command sets the face/colour configuration (state) of a typical solved Rubik cube.

```
127 \newcommand{\RubikCubeSolved}{%
128 \RubikFaceUpAll{W}%
129 \RubikFaceDownAll{Y}%
130 \RubikFaceLeftAll{B}%
131 \RubikFaceRightAll{G}%
132 \RubikFaceFrontAll{O}%
133 \RubikFaceBackAll{R}%
134 }
```

17.8 Slice commands

`\RubikSliceTopR` These 6 commands allocate the colour arguments for the 6 visible ordered facelets along a horizontal slice. There are three horizontal slices to consider (Top, Middle, Bottom) and each has two viewpoints. The colour-code arguments are ordered 1–6 from left to right. The terminal L and R denote the Left (L) viewpoint and Right (R) viewpoint versions. Note that the two legacy ‘Equator’ versions (now replaced by ‘Middle’) are retained (below) to allow backward compatibility.

```
135 \newcommand{\RubikSliceTopR}[6]{%
136 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
```

```

137 \def\Rlt{#4}\def\Rmt{#5}\def\Rrt{#6}%
138 }
139 \newcommand{\RubikSliceTopL}[6]{%
140 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
141 \def\Flt{#4}\def\Fmt{#5}\def\Frt{#6}%
142 }
143 \newcommand{\RubikSliceMiddleR}[6]{%
144 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
145 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
146 }
147 \newcommand{\RubikSliceMiddleL}[6]{%
148 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
149 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
150 }
151 \newcommand{\RubikSliceEquatorR}[6]{%
152 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
153 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
154 }
155 \newcommand{\RubikSliceEquatorL}[6]{%
156 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
157 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
158 }
159 \newcommand{\RubikSliceBottomR}[6]{%
160 \def\Flb{#1}\def\Fmb{#2}\def\Frb{#3}%
161 \def\Rlb{#4}\def\Rmb{#5}\def\Rrb{#6}%
162 }
163 \newcommand{\RubikSliceBottomL}[6]{%
164 \def\Llb{#1}\def\Lmb{#2}\def\Lrb{#3}%
165 \def\Flb{#4}\def\Fmb{#5}\def\Frb{#6}%
166 }

```

17.9 Cube drawing macros

Since the three visible sides of a Rubik cube have up to 27 non-grey colours, and $\text{\TeX}$ has only 9 macro parameters available, we are forced to draw Rubik cubes by first specifying the colours on each of the three faces, and then using a ‘DrawRubikCubeXY’ command, where the trailing XY code defines the view direction (X = either R, L; Y = either U, D). The order of the XY code is important: X first, Y second (so it is easy to remember).

On each face the facelets are drawn in the following order: Top row (left to right), Middle row (left to right), Bottom row (left to right).

The TikZ draw cycle for each facelet square on a Rubik cube face cycles through the four corners of the facelet in the following order: lb $\rightarrow$ lt $\rightarrow$ rt $\rightarrow$ rb; the code being lb (LeftBottom), lt (LeftTop), rt (RightTop), rb (RightBottom) (only need four coords); the grid origin is at the bottom-left corner of the FRONT face.

\DrawRubikCubeFrontFace This ‘FrontFace’ command is an ‘internal’ command which draws and paints all the facelets on the FRONT face of a Rubik cube. It is used by all of the cube drawing macros which display the FRONT face. The 9 colours are allocated by

an earlier `\RubikFaceFront` command. These Face macros are based, in part, on those of Peter Bartal (2011).

```

167 \newcommand{\DrawRubikCubeFrontFace}{%
168 % ---top row left to right
169 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
170 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
171 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
172 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
173 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
174 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
175 % ----middle row left to right
176 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
177 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
178 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
179 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
180 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
181 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
182 % ----bottom row left to right
183 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
184 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
185 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
186 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
187 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
188 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
189 }

```

17.9.1 Viewing direction

The command ‘`DrawRubikCubeXY`’ command uses the trailing XY code to specify the view direction (X = either R, L; Y = either U, D). The order of the XY code is important: X first, Y second (so it is easy to remember).

`\DrawRubikCubeRU` This command draws and paints a Rubik cube as viewed from the Right Upper (RU) viewpoint. It starts by using the internal command `\DrawRubikCubeFrontFace` to draw the FRONT face, and then draws the UP face followed by the RIGHT face. The colours are allocated to particular facelets using the `\RubikFaceUp`, `\RubikFaceRight` and `\RubikFaceFront` commands.

The (x,y) grid origin is at the bottom-left corner of the FRONT face. The perspective is designed so that the 2D graphic image of the side face (RIGHT in this particular case) has its ‘horizontal’ lines running at 45 degrees. This has the useful advantage that the 2D width of the side is exactly 1-unit, and so makes it easy to determine the 2D (x,y) coordinates of any position, and hence facilitates typesetting text onto the image of the cube using TikZ commands.

```

190 \newcommand{\DrawRubikCubeRU}{%
191 \DrawRubikCubeFrontFace %% frontface
192 %%-----Up face-----
193 %%---top row
194 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%

```

```

195 (0.66,3.66) -- (1,4) -- (2,4) -- (1.66,3.66) -- cycle;
196 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
197 (1.66,3.66) -- (2,4) -- (3,4) -- (2.66,3.66) -- cycle;
198 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
199 (2.66,3.66) -- (3,4) -- (4,4) -- (3.66,3.66) -- cycle;
200 %%---middle row
201 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
202 (0.33,3.33) -- (0.66,3.66) -- (1.66,3.66) -- (1.33,3.33) -- cycle;
203 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
204 (1.33,3.33) -- (1.66,3.66) -- (2.66,3.66) -- (2.33,3.33) -- cycle;
205 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
206 (2.33,3.33) -- (2.66,3.66) -- (3.66,3.66) -- (3.33,3.33) -- cycle;
207 %%---bottom row
208 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
209 (0,3) -- (0.33,3.33) -- (1.33,3.33) -- (1,3) -- cycle;
210 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
211 (1,3) -- (1.33,3.33) -- (2.33,3.33) -- (2,3) -- cycle;
212 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
213 (2,3) -- (2.33,3.33) -- (3.33,3.33) -- (3,3) -- cycle;
214 %%-----Right face-----
215 %%---top row
216 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
217 (3,2) -- (3, 3) -- (3.33,3.33) -- (3.33,2.33) -- cycle;
218 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
219 (3.33,2.33) -- (3.33, 3.33) -- (3.66,3.66) -- (3.66,2.66) -- cycle;
220 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
221 (3.66,2.66) -- (3.66, 3.66) -- (4,4) -- (4,3) -- cycle;
222 %%---middle row
223 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
224 (3,1) -- (3, 2) -- (3.33,2.33) -- (3.33,1.33) -- cycle;
225 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
226 (3.33,1.33) -- (3.33, 2.33) -- (3.66,2.66) -- (3.66,1.66) -- cycle;
227 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
228 (3.66,1.66) -- (3.66, 2.66) -- (4,3) -- (4,2) -- cycle;
229 %%---bottom row
230 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
231 (3,0) -- (3, 1) -- (3.33,1.33) -- (3.33,0.33) -- cycle;
232 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
233 (3.33,0.33) -- (3.33, 1.33) -- (3.66,1.66) -- (3.66,0.66) -- cycle;
234 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
235 (3.66,0.66) -- (3.66, 1.66) -- (4,2) -- (4,1) -- cycle;
236 }

```

`\DrawRubikCube` This command is equivalent to the previous `\DrawRubikCubeRU` and hence is the default form (i.e., if the trailing XY viewpoint code is accidentally omitted).

```
237 \newcommand{\DrawRubikCube}{\DrawRubikCubeRU}
```

`\DrawRubikCubeRD` This command draws and paints a Rubik cube as viewed from the Right Down (RD) viewpoint.

```

238 \newcommand{\DrawRubikCubeRD}{%
239 \DrawRubikCubeFrontFace %% frontface
240 %%-----Right face-----
241 %%---top row
242 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
243 (3,2) -- (3, 3) -- (3.33,2.66) -- (3.33,1.66) -- cycle;
244 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
245 (3.33,1.66) -- (3.33, 2.66) -- (3.66,2.33) -- (3.66,1.33) -- cycle;
246 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
247 (3.66,1.33) -- (3.66, 2.33) -- (4,2) -- (4,1) -- cycle;
248 %%---middle row
249 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
250 (3,1) -- (3, 2) -- (3.33,1.66) -- (3.33,0.66) -- cycle;
251 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
252 (3.33,0.66) -- (3.33, 1.66) -- (3.66,1.33) -- (3.66,0.33) -- cycle;
253 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
254 (3.66,0.33) -- (3.66, 1.33) -- (4,1) -- (4,0) -- cycle;
255 %%---bottom row
256 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
257 (3,0) -- (3, 1) -- (3.33,0.66) -- (3.33,-0.33) -- cycle;
258 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
259 (3.33,-0.33) -- (3.33, 0.66) -- (3.66,0.33) -- (3.66,-0.66) -- cycle;
260 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
261 (3.66,-0.66) -- (3.66, 0.33) -- (4,0) -- (4,-1) -- cycle;
262 %%-----Down face-----
263 %%---top row
264 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
265 (0.33,-0.33) -- (0, 0) -- (1,0) -- (1.33,-0.33) -- cycle;
266 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
267 (1.33,-0.33) -- (1, 0) -- (2,0) -- (2.33,-0.33) -- cycle;
268 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
269 (2.33,-0.33) -- (2, 0) -- (3,0) -- (3.33,-0.33) -- cycle;
270 %%---middle row
271 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
272 (0.66,-0.66) -- (0.33, -0.33) -- (1.33,-0.33) -- (1.66,-0.66) -- cycle;
273 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
274 (1.66,-0.66) -- (1.33, -0.33) -- (2.33,-0.33) -- (2.66,-0.66) -- cycle;
275 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
276 (2.66,-0.66) -- (2.33, -0.33) -- (3.33,-0.33) -- (3.66,-0.66) -- cycle;
277 %%---bottom row
278 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
279 (1,-1) -- (0.66, -0.66) -- (1.66,-0.66) -- (2,-1) -- cycle;
280 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
281 (2,-1) -- (1.66, -0.66) -- (2.66,-0.66) -- (3,-1) -- cycle;
282 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
283 (3,-1) -- (2.66, -0.66) -- (3.66,-0.66) -- (4,-1) -- cycle;
284 }

```

\DrawRubikCubeLD This command draws and paints a Rubik cube as viewed from the Left Down (LD) viewpoint.


```

285 \newcommand{\DrawRubikCubeLD}{%
286 \DrawRubikCubeFrontFace %% frontface
287 %%-----Left face-----
288 %%---top row
289 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
290 (-1,1) -- (-1, 2) -- (-0.66,2.33) -- (-0.66,1.33) -- cycle;
291 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
292 (-0.66,1.33) -- (-0.66, 2.33) -- (-0.33,2.66) -- (-0.33,1.66) -- cycle;
293 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
294 (-0.33,1.66) -- (-0.33, 2.66) -- (0,3) -- (0,2) -- cycle;
295 %%---middle row
296 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
297 (-1,0) -- (-1, 1) -- (-0.66,1.33) -- (-0.66,0.33) -- cycle;
298 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
299 (-0.66,0.33) -- (-0.66, 1.33) -- (-0.33,1.66) -- (-0.33,0.66) -- cycle;
300 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
301 (-0.33,0.66) -- (-0.33, 1.66) -- (0,2) -- (0,1) -- cycle;
302 %%---bottom row
303 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
304 (-1,-1) -- (-1, 0) -- (-0.66,0.33) -- (-0.66,-0.66) -- cycle;
305 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
306 (-0.66,-0.66) -- (-0.66, 0.33) -- (-0.33,0.66) -- (-0.33,-0.33) -- cycle;
307 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
308 (-0.33,-0.33) -- (-0.33, 0.66) -- (0,1) -- (0,0) -- cycle;
309 %%-----Down face-----
310 %%---top row
311 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
312 (-0.33,-0.33) -- (0, 0) -- (1,0) -- (0.66,-0.33) -- cycle;
313 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
314 (0.66,-0.33) -- (1, 0) -- (2,0) -- (1.66,-0.33) -- cycle;
315 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
316 (1.66,-0.33) -- (2, 0) -- (3,0) -- (2.66,-0.33) -- cycle;
317 %%---middle row
318 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
319 (-0.66,-0.66) -- (-0.33, -0.33) -- (0.66,-0.33) -- (0.33,-0.66) -- cycle;
320 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
321 (0.33,-0.66) -- (0.66, -0.33) -- (1.66,-0.33) -- (1.33,-0.66) -- cycle;
322 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
323 (1.33,-0.66) -- (1.66, -0.33) -- (2.66,-0.33) -- (2.33,-0.66) -- cycle;
324 %%---bottom row
325 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
326 (-1,-1) -- (-0.66, -0.66) -- (0.33,-0.66) -- (0,-1) -- cycle;
327 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
328 (0,-1) -- (0.33, -0.66) -- (1.33,-0.66) -- (1,-1) -- cycle;
329 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
330 (1,-1) -- (1.33, -0.66) -- (2.33,-0.66) -- (2,-1) -- cycle;
331 }

```

\DrawRubikCubeLU This command draws and paints a Rubik cube as viewed from the Left Up (LU) viewpoint.

```

332 \newcommand{\DrawRubikCubeLU}{%
333 \DrawRubikCubeFrontFace %% frontface
334 %%-----Left face-----
335 %%---top row
336 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
337 (-1,3) -- (-1, 4) -- (-0.66,3.66) -- (-0.66,2.66) -- cycle;
338 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
339 (-0.66,2.66) -- (-0.66, 3.66) -- (-0.33,3.33) -- (-0.33,2.33) -- cycle;
340 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
341 (-0.33,2.33) -- (-0.33, 3.33) -- (0,3) -- (0,2) -- cycle;
342 %%---middle row
343 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
344 (-1,2) -- (-1, 3) -- (-0.66,2.66) -- (-0.66,1.66) -- cycle;
345 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
346 (-0.66,1.66) -- (-0.66, 2.66) -- (-0.33,2.33) -- (-0.33,1.33) -- cycle;
347 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
348 (-0.33,1.33) -- (-0.33, 2.33) -- (0,2) -- (0,1) -- cycle;
349 %%---bottom row
350 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
351 (-1,1) -- (-1, 2) -- (-0.66,1.66) -- (-0.66,0.66) -- cycle;
352 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
353 (-0.66,0.66) -- (-0.66, 1.66) -- (-0.33,1.33) -- (-0.33,0.33) -- cycle;
354 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
355 (-0.33,0.33) -- (-0.33, 1.33) -- (0,1) -- (0,0) -- cycle;
356 %%-----Up face-----
357 %%---top row
358 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
359 (-0.66,3.66) -- (-1, 4) -- (0,4) -- (0.33,3.66) -- cycle;
360 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
361 (0.33,3.66) -- (0, 4) -- (1,4) -- (1.33,3.66) -- cycle;
362 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
363 (1.33,3.66) -- (1, 4) -- (2,4) -- (2.33,3.66) -- cycle;
364 %%---middle row
365 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
366 (-0.33,3.33) -- (-0.66, 3.66) -- (0.33,3.66) -- (0.66,3.33) -- cycle;
367 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
368 (0.66,3.33) -- (0.33, 3.66) -- (1.33,3.66) -- (1.66,3.33) -- cycle;
369 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
370 (1.66,3.33) -- (1.33, 3.66) -- (2.33,3.66) -- (2.66,3.33) -- cycle;
371 %%---bottom row
372 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
373 (0,3) -- (-0.33, 3.33) -- (0.66,3.33) -- (1,3) -- cycle;
374 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
375 (1,3) -- (0.66, 3.33) -- (1.66,3.33) -- (2,3) -- cycle;
376 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
377 (2,3) -- (1.66, 3.33) -- (2.66,3.33) -- (3,3) -- cycle;%
378 \ %%trailing space
379 }

```

17.10 LayerFace commands

`\DrawRubikLayerFace` These two LayerFace commands each draw and paint a single face of 9 facelets. The first command takes 9 ordered colour parameters, (ordered in layers from top left to bottom right, so #1 is the placeholder for the colour of the TopLeft facelet etc.) The second takes only one colour parameter (since All the colours are the same). The drawing origin (0,0) = bottom left corner. The facelets are drawn from left to right. NOTE: this macro is SAME as the internal command `\DrawRubikCubeFrontFace` which is used for drawing the front face of a Rubik cube.

```

380 \newcommand{\DrawRubikLayerFace}[9]{%
381 %%-----FRONT face-----
382 %%---top row
383 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
384 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
385 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
386 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
387 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
388 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
389 %%-----middle row
390 \draw[line join=round,line cap=round,ultra thick,fill=#4]%
391 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
392 \draw[line join=round,line cap=round,ultra thick,fill=#5]%
393 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
394 \draw[line join=round,line cap=round,ultra thick,fill=#6]%
395 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
396 %%---bottom row
397 \draw[line join=round,line cap=round,ultra thick,fill=#7]%
398 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
399 \draw[line join=round,line cap=round,ultra thick,fill=#8]%
400 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
401 \draw[line join=round,line cap=round,ultra thick,fill=#9]%
402 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
403 }
404 \newcommand{\DrawRubikLayerFaceAll}[1]{%
405 %%-----FRONT face-----
406 %%---top row
407 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
408 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
409 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
410 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
411 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
412 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
413 %%-----middle row
414 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
415 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
416 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
417 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
418 \draw[line join=round,line cap=round,ultra thick,fill=#1]%

```

```

419 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
420 %%----bottom row
421 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
422 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
423 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
424 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
425 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
426 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
427 }

```

17.11 DrawFlatX commands

[NOTE: These new commands (version 3.0) were modified from the earlier `\FlatUp`, `\FlatDown` etc., commands; i.e., they were reformulated as a set of `\Draw...` commands to make them consistent with all the other `\Draw..` commands].

`\DrawFlatUp` Each of these commands draws a separate (flat) face (9 facelets). Each command (except `\DrawFlatFront`) takes two arguments, namely the X-coordinate and Y-coordinate of the bottom-left corner of the face. This (X,Y) pair of coordinates therefore allows the user to position the face. These commands were motivated by a need to be able to show hidden faces under certain circumstances.

`\DrawFlatDown`

`\DrawFlatLeft`

`\DrawFlatRight`

`\DrawFlatFront`

`\DrawFlatBack`

Note that the Y-argument currently only works fully with the `\DrawFlatUp`, `\DrawFlatDown` and `\DrawFlatBack` commands, since all the other faces currently only require $Y=0$ (this will be made more flexible in a later version).

Note also that the `\DrawFlatFront` command takes no arguments, since by definition the bottom left corner of this face is at (0,0), and there seems to be no reason (just now) for this face to have the facility to be positioned otherwise.

EXAMPLE: The following command positions the Up face so that its bottom left corner is located at (0,3):

```
\DrawFlatUp{0}{3}
```

These new commands are also used by the commands `\DrawRubikFlat` and `\DrawRubikCubeFlat` to draw various ‘flat’ representations of a Rubik cube.

The (x,y) variables are here encoded as (`\ux`, `\uy`) where the ‘u’ stands for Up etc. However, since we are unable to use ‘dx, dy’ with the `\DrawFlatDown` command (since dx and dy are already used in the `\cube@dxdydz...` command) we encode these instead as (`\ddx`, `\ddy`).

```

428 \newcommand{\DrawFlatUp}[2]{%
429 \pgfmathsetmacro{\ux}{#1}%
430 \pgfmathsetmacro{\uy}{#2}%
431 %%---top row
432 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
433 (\ux + 0,\uy + 2) -- (\ux + 0,\uy + 3) -- (\ux + 1,\uy + 3)%
434 -- (\ux + 1,\uy + 2) -- cycle;
435 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
436 (\ux + 1,\uy + 2) -- (\ux + 1,\uy + 3) -- (\ux + 2,\uy + 3)%
437 -- (\ux + 2,\uy + 2) -- cycle;

```

```

438 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
439 (\ux + 2,\uy + 2) -- (\ux + 2,\uy + 3) -- (\ux + 3,\uy + 3)%
440 -- (\ux + 3,\uy + 2) -- cycle;
441 %%-----middle row
442 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
443 (\ux + 0,\uy + 1) -- (\ux + 0,\uy + 2) -- (\ux + 1,\uy + 2)%
444 -- (\ux + 1,\uy + 1) -- cycle;
445 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
446 (\ux + 1,\uy + 1) -- (\ux + 1,\uy + 2) -- (\ux + 2,\uy + 2)%
447 -- (\ux + 2,\uy + 1) -- cycle;
448 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
449 (\ux + 2,\uy + 1) -- (\ux + 2,\uy + 2) -- (\ux + 3,\uy + 2)%
450 -- (\ux + 3,\uy + 1) -- cycle;
451 %%-----bottom row
452 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
453 (\ux + 0,\uy + 0) -- (\ux + 0,\uy + 1) -- (\ux + 1,\uy + 1)%
454 -- (\ux + 1,\uy + 0) -- cycle;
455 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
456 (\ux + 1,\uy + 0) -- (\ux + 1,\uy + 1) -- (\ux + 2,\uy + 1)%
457 -- (\ux + 2,\uy + 0) -- cycle;
458 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
459 (\ux + 2,\uy + 0) -- (\ux + 2,\uy + 1) -- (\ux + 3,\uy + 1)%
460 -- (\ux + 3,\uy + 0) -- cycle;
461 }
462 %%-----
463 \newcommand{\DrawFlatDown}[2]{%
464 \pgfmathsetmacro{\ddx}{#1}%
465 \pgfmathsetmacro{\ddy}{#2}%
466 %%---top row
467 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
468 (\ddx + 0,\ddy + 2) -- (\ddx + 0,\ddy + 3) -- (\ddx + 1,\ddy + 3)%
469 -- (\ddx + 1,\ddy + 2) -- cycle;
470 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
471 (\ddx + 1,\ddy + 2) -- (\ddx + 1,\ddy + 3) -- (\ddx + 2,\ddy + 3)%
472 -- (\ddx + 2,\ddy + 2) -- cycle;
473 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
474 (\ddx + 2,\ddy + 2) -- (\ddx + 2,\ddy + 3) -- (\ddx + 3,\ddy + 3)%
475 -- (\ddx + 3,\ddy + 2) -- cycle;
476 %%-----middle row
477 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
478 (\ddx + 0,\ddy + 1) -- (\ddx + 0,\ddy + 2) -- (\ddx + 1,\ddy + 2)%
479 -- (\ddx + 1,\ddy + 1) -- cycle;
480 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
481 (\ddx + 1,\ddy + 1) -- (\ddx + 1,\ddy + 2) -- (\ddx + 2,\ddy + 2)%
482 -- (\ddx + 2,\ddy + 1) -- cycle;
483 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
484 (\ddx + 2,\ddy + 1) -- (\ddx + 2,\ddy + 2) -- (\ddx + 3,\ddy + 2)%
485 -- (\ddx + 3,\ddy + 1) -- cycle;
486 %%-----bottom row
487 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%

```

```

488 (\ddx + 0,\ddy + 0) -- (\ddx + 0,\ddy + 1) -- (\ddx + 1,\ddy + 1)%
489 -- (\ddx + 1,\ddy + 0) -- cycle;
490 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
491 (\ddx + 1,\ddy + 0) -- (\ddx + 1,\ddy + 1) -- (\ddx + 2,\ddy + 1)%
492 -- (\ddx + 2,\ddy + 0) -- cycle;
493 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
494 (\ddx + 2,\ddy + 0) -- (\ddx + 2,\ddy + 1) -- (\ddx + 3,\ddy + 1)%
495 -- (\ddx + 3,\ddy + 0) -- cycle;
496 }
497 %%-----
498 \newcommand{\DrawFlatLeft}[2]{%
499 \pgfmathsetmacro{\lx}{#1}%
500 \pgfmathsetmacro{\ly}{#2}%
501 %% NOTE: y variable coord not yet implemented
502 %%---top row
503 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
504 (\lx + 0,2) -- (\lx + 0, 3) -- (\lx + 1,3) -- (\lx + 1,2) -- cycle;
505 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
506 (\lx + 1,2) -- (\lx + 1, 3) -- (\lx + 2,3) -- (\lx + 2,2) -- cycle;
507 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
508 (\lx + 2,2) -- (\lx + 2, 3) -- (\lx + 3,3) -- (\lx + 3,2) -- cycle;
509 %%----middle row
510 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
511 (\lx + 0,1) -- (\lx + 0, 2) -- (\lx + 1,2) -- (\lx + 1,1) -- cycle;
512 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
513 (\lx + 1,1) -- (\lx + 1, 2) -- (\lx + 2,2) -- (\lx + 2,1) -- cycle;
514 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
515 (\lx + 2,1) -- (\lx + 2, 2) -- (\lx + 3,2) -- (\lx + 3,1) -- cycle;
516 %%---bottom row
517 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
518 (\lx + 0,0) -- (\lx + 0, 1) -- (\lx + 1,1) -- (\lx + 1,0) -- cycle;
519 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
520 (\lx + 1,0) -- (\lx + 1, 1) -- (\lx + 2,1) -- (\lx + 2,0) -- cycle;
521 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
522 (\lx + 2,0) -- (\lx + 2, 1) -- (\lx + 3,1) -- (\lx + 3,0) -- cycle;
523 }
524 %%-----
525 \newcommand{\DrawFlatRight}[2]{%
526 \pgfmathsetmacro{\rx}{#1}% %3
527 \pgfmathsetmacro{\ry}{#2}% %0
528 %% NOTE: y variable coord not yet implemented
529 %%---top row
530 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
531 (\rx + 0,2) -- (\rx + 0, 3) -- (\rx + 1,3) -- (\rx + 1,2) -- cycle;
532 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
533 (\rx + 1,2) -- (\rx + 1, 3) -- (\rx + 2,3) -- (\rx + 2,2) -- cycle;
534 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
535 (\rx + 2,2) -- (\rx + 2, 3) -- (\rx + 3,3) -- (\rx + 3,2) -- cycle;
536 %%----middle row
537 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%

```

```

538 (\rx + 0,1) -- (\rx + 0, 2) -- (\rx + 1,2) -- (\rx + 1,1) -- cycle;
539 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
540 (\rx + 1,1) -- (\rx + 1, 2) -- (\rx + 2,2) -- (\rx + 2,1) -- cycle;
541 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
542 (\rx + 2,1) -- (\rx + 2, 2) -- (\rx + 3,2) -- (\rx + 3,1) -- cycle;
543 %%---bottom row
544 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
545 (\rx + 0,0) -- (\rx + 0, 1) -- (\rx + 1,1) -- (\rx + 1,0) -- cycle;
546 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
547 (\rx + 1,0) -- (\rx + 1, 1) -- (\rx + 2,1) -- (\rx + 2,0) -- cycle;
548 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
549 (\rx + 2,0) -- (\rx + 2, 1) -- (\rx + 3,1) -- (\rx + 3,0) -- cycle;
550 }
551 %%-----
552 \newcommand{\DrawFlatFront}{%
553 %% This command is used /only/ by the \cmd{\DrawRubikFlat} command.
554 %% NOTE: x, y variables not implemented as not required here
555 %%---top row
556 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
557 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
558 %%
559 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
560 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
561 %%
562 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
563 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
564 %%----middle row
565 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
566 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
567 %%
568 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
569 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
570 %%
571 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
572 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
573 %%---bottom row
574 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
575 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
576 %%
577 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
578 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
579 %%
580 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
581 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
582 }
583 %%-----
584 \newcommand{\DrawFlatBack}[2]{%
585 \pgfmithsetmacro{\bx}{#1}%
586 \pgfmithsetmacro{\by}{#2}%
587 %%---top row

```

```

588 \draw[line join=round,line cap=round,ultra thick,fill=\Blt]%
589 (\bx + 0,\by + 2) -- (\bx + 0,\by + 3) -- (\bx + 1,\by + 3)%
590 -- (\bx + 1,\by + 2) -- cycle;
591 \draw[line join=round,line cap=round,ultra thick,fill=\Bmt]%
592 (\bx + 1,\by + 2) -- (\bx + 1,\by + 3) -- (\bx + 2,\by + 3)%
593 -- (\bx + 2,\by + 2) -- cycle;
594 \draw[line join=round,line cap=round,ultra thick,fill=\Brt]%
595 (\bx + 2,\by + 2) -- (\bx + 2,\by + 3) -- (\bx + 3,\by + 3)%
596 -- (\bx + 3,\by + 2) -- cycle;
597 %%----middle row
598 \draw[line join=round,line cap=round,ultra thick,fill=\Blm]%
599 (\bx + 0,\by + 1) -- (\bx + 0,\by + 2) -- (\bx + 1,\by + 2)%
600 -- (\bx + 1,\by + 1) -- cycle;
601 \draw[line join=round,line cap=round,ultra thick,fill=\Bmm]%
602 (\bx + 1,\by + 1) -- (\bx + 1,\by + 2) -- (\bx + 2,\by + 2)%
603 -- (\bx + 2,\by + 1) -- cycle;
604 \draw[line join=round,line cap=round,ultra thick,fill=\Brm]%
605 (\bx + 2,\by + 1) -- (\bx + 2,\by + 2) -- (\bx + 3,\by + 2)%
606 -- (\bx + 3,\by + 1) -- cycle;
607 %%----bottom row
608 \draw[line join=round,line cap=round,ultra thick,fill=\Blb]%
609 (\bx + 0,\by + 0) -- (\bx + 0,\by + 1) -- (\bx + 1,\by + 1)%
610 -- (\bx + 1,\by + 0) -- cycle;
611 \draw[line join=round,line cap=round,ultra thick,fill=\Bmb]%
612 (\bx + 1,\by + 0) -- (\bx + 1,\by + 1) -- (\bx + 2,\by + 1)%
613 -- (\bx + 2,\by + 0) -- cycle;
614 \draw[line join=round,line cap=round,ultra thick,fill=\Brb]%
615 (\bx + 2,\by + 0) -- (\bx + 2,\by + 1) -- (\bx + 3,\by + 1)%
616 -- (\bx + 3,\by + 0) -- cycle;
617 }

```

`\DrawRubikFlat` Draws a standard flat representation of the Rubik cube (colours only). Note that `\DrawFlatFront` does not take any arguments (x,y) arguments.

```

618 \newcommand{\DrawRubikFlat}{%
619   \DrawFlatUp{0}{3}%
620   \DrawFlatDown{0}{-3}%
621   \DrawFlatLeft{-3}{0}%
622   \DrawFlatFront%
623   \DrawFlatRight{3}{0}%
624   \DrawFlatBack{6}{0}%
625 }

```

`\DrawRubikCubeFlat` Draws a Rubik cube together with the three hidden faces (colours only) in a semi-flat representation. The (x,y) arguments are for the bottom-left corner of the face.

```

626 \newcommand{\DrawRubikCubeFlat}{%
627   \DrawRubikCube%
628   \DrawFlatDown{0}{-3}%
629   \DrawFlatLeft{-3}{0}%

```



```

630 \DrawFlatBack{4}{1}%
631 }

```

17.11.1 DrawFlatXSide commands

These six commands draw a face together with all four sidebars (colours only). We use the `\DrawFlatX` commands to draw the face. We use the `\DrawRubikLayerSideX` commands to draw the sidebars. The parameter orders for the `\DrawRubikLayerSideX` commands are as follows: Top (T) and Bottom (B) = left to right; Left (L) and Right (R) = top to bottom; (see the `\DrawRubikLayerSideX` command for details of the arguments).

`\DrawFlatUpSide` Draws the UP face together with all four sidebars (colours only).

```

632 \newcommand{\DrawFlatUpSide}{%
633 \DrawFlatUp{0}{0}%
634 \DrawRubikLayerSideT{\BrT}{\BmT}{\BlT}%
635 \DrawRubikLayerSideL{\Lt}{\Lm}{\Lr}%
636 \DrawRubikLayerSideR{\Rr}{\Rm}{\Rl}%
637 \DrawRubikLayerSideB{\Fl}{\Fm}{\Fr}%
638 }

```

`\DrawFlatFrontSide` Draws the FRONT face together with all four sidebars (colours only).

```

639 \newcommand{\DrawFlatFrontSide}{%
640 \DrawFlatFront{0}{0}%
641 \DrawRubikLayerSideT{\Ul}{\Um}{\Ur}%
642 \DrawRubikLayerSideL{\Lr}{\Lm}{\Lb}%
643 \DrawRubikLayerSideR{\Rl}{\Rm}{\Rb}%
644 \DrawRubikLayerSideB{\Dl}{\Dm}{\Dr}%
645 }

```

`\DrawFlatRightSide` Draws the RIGHT face together with all four sidebars (colours only).

```

646 \newcommand{\DrawFlatRightSide}{%
647 \DrawFlatRight{0}{0}%
648 \DrawRubikLayerSideT{\Ur}{\Um}{\Urt}%
649 \DrawRubikLayerSideL{\Fr}{\Fm}{\Frb}%
650 \DrawRubikLayerSideR{\Bl}{\Bm}{\Blb}%
651 \DrawRubikLayerSideB{\Dr}{\Dm}{\Drb}%
652 }

```

`\DrawFlatLeftSide` Draws the LEFT face together with all four sidebars (colours only).

```

653 \newcommand{\DrawFlatLeftSide}{%
654 \DrawFlatLeft{0}{0}%
655 \DrawRubikLayerSideT{\Ul}{\Um}{\Ulb}%
656 \DrawRubikLayerSideL{\Br}{\Bm}{\Brb}%
657 \DrawRubikLayerSideR{\Fl}{\Fm}{\Flb}%
658 \DrawRubikLayerSideB{\Dl}{\Dm}{\Dlb}%
659 }

```

`\DrawFlatBackSide` Draws the BACK face together with all four sidebars (colours only).

```
660 \newcommand{\DrawFlatBackSide}{%
661 \DrawFlatBack{0}{0}%
662 \DrawRubikLayerSideT{\Urt}{\Umt}{\Ult}%
663 \DrawRubikLayerSideL{\Rrt}{\Rrm}{\Rrb}%
664 \DrawRubikLayerSideR{\Llt}{\Llm}{\Llb}%
665 \DrawRubikLayerSideB{\Drb}{\Dmb}{\Dlb}%
666 }
```

`\DrawFlatDownSide` Draws the DOWN face together with all four sidebars (colours only).

```
667 \newcommand{\DrawFlatDownSide}{%
668 \DrawFlatDown{0}{0}%
669 \DrawRubikLayerSideT{\Flb}{\Fmb}{\Frb}%
670 \DrawRubikLayerSideL{\Lrb}{\Lmb}{\Llb}%
671 \DrawRubikLayerSideR{\Rlb}{\Rmb}{\Rrb}%
672 \DrawRubikLayerSideB{\Brb}{\Bmb}{\Blb}%
673 }
```

17.12 SideBar commands

SideBar commands draw narrow bars of colour indicating the side colours of each of the facelets forming the side of a given layer (face). Each SideBar is the length of a single facelet.

`\RubikSideBarWidth` These three commands allow the user to set the Width, Length and Separation
`\RubikSideBarLength` parameters for the sidebar (in decimal values, where 1 is equivalent to the length
`\RubikSideBarSep` of the side of a facelet).

```
674 \newcommand{\RubikSideBarWidth}[1]{\pgfmathsetmacro{\bw}{#1}}
675 \newcommand{\RubikSideBarLength}[1]{\pgfmathsetmacro{\bl}{#1}}
676 \newcommand{\RubikSideBarSep}[1]{\pgfmathsetmacro{\bs}{#1}}
```

We first set some default values

```
677 \RubikSideBarWidth{0.3}%
678 \RubikSideBarLength{1}%
679 \RubikSideBarSep{0.3}%
```

17.12.1 Allocating a colour to a single facelet sidebar

`\side@barT` Internal commands. Full length face SideBars are really multiple instances of
`\side@barB` single facelet bars, each of which is drawn using one of four internal SideBar
`\side@barL` commands—one for each of the sides which we shall call Top, Bottom, Left, Right.
`\side@barR` Each SideBar command takes two arguments: one for facelet position $\{1 \mid 2 \mid 3\}$
and one for the colour-code $\{R \mid O \mid Y \mid G \mid B \mid W \mid X\}$.

EXAMPLE: the following command allocates a colour to a single facelet sidebar on the Left of a Rubik face:

```
\side@barL{\facelet-position}{\colour-code}
```

There are three facelet positions on each of the four sides of a face, and these are numbered 1 to 3 starting from the bottom left corner (1,1). The `SideBar` command also implements the set (or default) Length (`\bl`), Width (`\bw`) and Separation (`\bs`) values mentioned above. $\text{\blh} = \text{Half } \text{\bl} = \text{\bl}/2$. Note that the TikZ `\pgfmathsetmacro` commands (which do the maths) must be inside the TeX sidebar command in order to work. The start point of the TikZ `\draw` command for each bar rectangle is bottom Left corner of the bar $= (\text{\dx}, \text{\dy})$

```

680 \newcommand{\side@barL}[2]{%
681 %% #1 = cubie possn no, #2 = colour
682 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
683 \pgfmathsetmacro{\dx}{0 - \bs - \bw}%
684 \pgfmathsetmacro{\dy}{#1-1+0.5-\blh}%
685 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
686 -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
687 }
688 \newcommand{\side@barR}[2]{%
689 %% #1 = cubie possn no, #2 = colour
690 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
691 \pgfmathsetmacro{\dx}{3 + \bs}%
692 \pgfmathsetmacro{\dy}{#1 -1+0.5-\blh}%
693 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
694 -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
695 }
696 \newcommand{\side@barT}[2]{%
697 %% #1 = cubie possn no, #2 = colour
698 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
699 \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
700 \pgfmathsetmacro{\dy}{3 + \bs}%
701 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
702 -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
703 }
704 \newcommand{\side@barB}[2]{%
705 %% #1 = cubie possn no, #2 = colour
706 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
707 \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
708 \pgfmathsetmacro{\dy}{0 - \bs - \bw}%
709 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
710 -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
711 }

```

17.12.2 Drawing a single facelet sidebar

`\DrawRubikLayerSideX1X2X3`

This command draws a single facelet sidebar using the above `\sidebar` command. The $X_1X_2X_3$ parameters refer to the options Left, Middle, Right, Top, Middle, Bottom, x, y, as follows:

X_1 is an x parameter: either $\langle L \mid M \mid R \rangle$
 X_2 is an y parameter: either $\langle T \mid M \mid B \rangle$

X_3 is an extra parameter: either $\langle x | y \rangle$, required by corner sidebars to indicate whether the sidebar was either above or below $\langle y \rangle$, or to the left or right $\langle x \rangle$ of the associated cubie. An X_3 parameter is not required for the sidebar of an edge cubie, since only one location is possible in these cases.

For example, the following command

`\DrawRubikLayerSideLTy{G}`

draws a Green sidebar above the Top Left cubie.

```

712 %---Left side
713 \newcommand{\DrawRubikLayerSideLTx}[1]{\side@barL{3}{#1}}
714 \newcommand{\DrawRubikLayerSideLMx}[1]{\side@barL{2}{#1}}
715 \newcommand{\DrawRubikLayerSideLM}[1]{\side@barL{2}{#1}}
716 \newcommand{\DrawRubikLayerSideLBx}[1]{\side@barL{1}{#1}}
717 %---Right side
718 \newcommand{\DrawRubikLayerSideRTx}[1]{\side@barR{3}{#1}}
719 \newcommand{\DrawRubikLayerSideRMx}[1]{\side@barR{2}{#1}}
720 \newcommand{\DrawRubikLayerSideRM}[1]{\side@barR{2}{#1}}
721 \newcommand{\DrawRubikLayerSideRBx}[1]{\side@barR{1}{#1}}
722 %---Top side
723 \newcommand{\DrawRubikLayerSideLTy}[1]{\side@barT{1}{#1}}
724 \newcommand{\DrawRubikLayerSideMTy}[1]{\side@barT{2}{#1}}
725 \newcommand{\DrawRubikLayerSideMT}[1]{\side@barT{2}{#1}}
726 \newcommand{\DrawRubikLayerSideRTy}[1]{\side@barT{3}{#1}}
727 %---Bottom side
728 \newcommand{\DrawRubikLayerSideLBy}[1]{\side@barB{1}{#1}}
729 \newcommand{\DrawRubikLayerSideMBy}[1]{\side@barB{2}{#1}}
730 \newcommand{\DrawRubikLayerSideMB}[1]{\side@barB{2}{#1}}
731 \newcommand{\DrawRubikLayerSideRBy}[1]{\side@barB{3}{#1}}

```

17.12.3 Drawing multiple cubie sidebars

<code>\DrawRubikLayerSideT</code> <code>\DrawRubikLayerSideB</code> <code>\DrawRubikLayerSideL</code> <code>\DrawRubikLayerSideR</code>	These commands allow the drawing of 3 small sidebars along one particular side (Top, Bottom, Left, Right), as indicated by the appended T, B, L, R letter code. Each command takes three ordered colour arguments, which are ordered either from left to right (the T and B forms), or from top to bottom (the L and R forms)
--	--

```

732 %---Top side---
733 \newcommand{\DrawRubikLayerSideT}[3]{%
734   \DrawRubikLayerSideLTy{#1}%
735   \DrawRubikLayerSideMTy{#2}%
736   \DrawRubikLayerSideRTy{#3}%
737 }
738 %---Bottom side---
739 \newcommand{\DrawRubikLayerSideB}[3]{%
740   \DrawRubikLayerSideLBy{#1}%
741   \DrawRubikLayerSideMBy{#2}%

```

```

742 \DrawRubikLayerSideRBy{#3}%
743 }
744 %%--Left side-----
745 %% colours run vertically DOWN
746 \newcommand{\DrawRubikLayerSideL}[3]{%
747   \DrawRubikLayerSideLTx{#1}%
748   \DrawRubikLayerSideLMx{#2}%
749   \DrawRubikLayerSideLBx{#3}%
750 }
751 %%--Right side-----
752 %% colours run vertically DOWN
753 \newcommand{\DrawRubikLayerSideR}[3]{%
754   \DrawRubikLayerSideRTx{#1}%
755   \DrawRubikLayerSideRMx{#2}%
756   \DrawRubikLayerSideRBx{#3}%
757 }

```

\DrawRubikLayerSideLR This command draws six cubie sidebars, three on each side, drawn in (L, R) pairs. The command takes six colour arguments, ordered in pairs, as shown in the following example.

```

\DrawRubikLayerSideLR{G}   {G}
                        {R}   {B}
                        {Y}   {B}

```

```

758 \newcommand{\DrawRubikLayerSideLR}[6]{%
759   \DrawRubikLayerSideLTx{#1}%
760   \DrawRubikLayerSideRTx{#2}%
761   \DrawRubikLayerSideLMx{#3}%
762   \DrawRubikLayerSideRMx{#4}%
763   \DrawRubikLayerSideLBx{#5}%
764   \DrawRubikLayerSideRBx{#6}%
765 }

```

17.13 NCube command

HISTORY: The essence of this command was originally developed by Peter Bartal as his command `\rubikcube` (see Bartal, 2011). We have modified it, as follows (June 2012):

- (1) adjusted to use the TikZ `\pgfmathsetmacro{}{}{}` command (suggested by Peter Grill),
- (2) renamed to `\DrawNCubeAll`.

\DrawNCubeAll This command draws a solved $N \times N \times N$ Rubik's cube from the RightUp viewpoint. All cubies on a given face have the same colour. The command takes four ordered arguments, as follows:

- #1 = number of cubies ($n > 0$) along each side,
- #2, #3, #4 = colors of the visible faces (in X,Y,Z order); X=Right face colour, Y=Up face colour, Z=Front face colour.

We use the `\pgfmathsetmacro{<variable-name>}{<numeric value or maths>}` command. Note that the second argument must not involve any units—just numeric values or mathematics.

```

766 \newcommand{\DrawNCubeAll}[4]{%
767   \pgfmathsetmacro{\ncubes}{#1-1}%
768   %% need to subtract 1 from the given number of cubies per side
769   %% to avoid the origin of the initial cube to be displaced
770   \foreach \x in {0,...,\ncubes}{%
771     \foreach \y in {0,...,\ncubes}{%
772       \foreach \z in {0,...,\ncubes}{%
773         \cube@dx dy dz{1}{#2}{#3}{#4}{\x}{\y}{\z}%
774       }}}}

```

`\cube@dx dy dz` This internal command is used only by the `\DrawNCubeAll` command. The original version of this command was developed by Peter Bartal (see Bartal, 2011). It was modified (2012) by RWD Nickalls (to implement a more intuitive X, Y, Z ordering of parameters).

The cube need not be in the origin, the distances of the DOWN-behind [L] corner from the origin are taken as parameters 5,6,7. The command takes 7 ordered arguments:

- 1 - length of an edge
- 2 - X-face colour (RIGHT face)
- 3 - Y-face colour (UP face)
- 4 - Z-face colour (FRONT face)
- 5 - x-position in space
- 6 - y-position in space
- 7 - z-position in space

USAGE: `\cube@dx dy dz{1}{X}{Y}{Z}{x}{y}{z}`

The original code `\pgfmathparse{#1+#5}\let\dy\pgfmathresult` was changed to the more intuitive `\pgfmathsetmacro{\dx}{#1+#5}` (suggested by Peter Grill 2011).

CHANGES: RWD Nickalls (2012): (1) added the `[line join=round,line cap=round]` options to each of the TikZ `\draw` commands, in order to improve the line joining (first two options); (2) adjusted the `\cube@dx dy dz` macro to adopt the ordered XYZ face colour notation (by reassigning #2, #3, #4).

```

775 \newcommand{\cube@dx dy dz}[7]{%
776   \pgfmathsetmacro{\dx}{#1+#5}%
777   %% calculates the 'displacement' (distance from the origin) of the
778   %% far corners of the cube along the x axis from the arguments
779   \pgfmathsetmacro{\dy}{#1+#6}%
780   %% calculates the 'displacement' (distance from the origin) of the
781   %% far corners of the cube along the y axis from the arguments
782   \pgfmathsetmacro{\dz}{#1+#7}%
783   %% calculates the 'displacement' (distance from the origin) of the
784   %% far corners of the cube along the z axis from the arguments
785   %% Draw FRONT face (using the X colour = #4)

```

```

786 \draw[line join=round,line cap=round,ultra thick,fill=#4]%
787 (#5,#6,\dz) -- (\dx,#6,\dz) -- (\dx,\dy,\dz) -- (#5,\dy,\dz) -- cycle;
788 %% The 'rectangle' command does not work with 3D coordinates,
789 %% so this is the way to draw the squares with space coordinates
790 %% Draw UP face (using the Y colour = #3)
791 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
792 (#5,\dy,\dz) -- (\dx,\dy,\dz) -- (\dx,\dy,#7) -- (#5,\dy,#7) -- cycle;
793 %% Draw RIGHT face (using the X colour = #2)
794 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
795 (\dx,#6,\dz) -- (\dx,#6,#7) -- (\dx,\dy,#7) -- (\dx,\dy,\dz) -- cycle;
796 }

```

17.14 Drawing single cubies

`\Cubiedx` These two commands set the value of the two length parameters `cx` and `cy`, and
`\Cubiedy` allow the user to vary the size (adjust `cy`) and horizontal viewpoint (adjust `cx`) of a
single cubie (described in more detail in the RUBIKCUBE package documentation).
Note that we cannot use the names `dx`, `dy` for variables since these have been
allocated already (see above). However, we do use `dx`, `dy` in the command names
as these will be more readily understood by the user.

```

797 \newcommand{\Cubiedx}[1]{\pgfmathsetmacro{cx}{#1}}
798 \newcommand{\Cubiedy}[1]{\pgfmathsetmacro{cy}{#1}}

```

We now set the default values (`cx=cy=0.4`)

```

799 \Cubiedx{0.4}
800 \Cubiedy{0.4}

```

`\DrawCubieRU` These four commands draw a single cubie from the RightUp, RightDown, LeftUp,
`\DrawCubieRD` LeftDown viewpoint. The viewpoint is specified using an appended two-letter XY
`\DrawCubieLU` ordered viewpoint code: either RU, RD, LU, LD. These commands take three
`\DrawCubieLD` arguments, namely three different XYZ ordered colour codes (R,O,Y,G,B,W,X).
FORMAT: `\DrawCubieRU{<Xcolour>}{<Ycolour>}{<Zcolour>}`
USAGE: `\DrawCubieRU{G}{B}{W}`

```

801 \newcommand{\DrawCubieRU}[3]{%
802 %% Front face (z)
803 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
804 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
805 %% Up face(y)
806 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
807 (0,1) -- (\cx, 1+\cy) -- (1+\cx,1+\cy) -- (1,1) -- cycle;
808 %% Right face(x)
809 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
810 (1,0) -- (1,1) -- (1+\cx,1+\cy) -- (1+\cx, \cy) -- cycle;
811 }
812 \newcommand{\DrawCubieRD}[3]{%
813 %% Front face (z)
814 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
815 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;

```

```

816 %% Down face (y)
817 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
818 (\cx,-\cy) -- (0, 0) -- (1,0) -- (1+\cx,-\cy) -- cycle;
819 %% Right face (x)
820 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
821 (1,0) -- (1,1) -- (1+\cx,-\cy+1) -- (1+\cx, -\cy) -- cycle;
822 }
823 \newcommand{\DrawCubieLD}[3]{%
824 %% Front face (z)
825 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
826 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
827 %% Down face (y)
828 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
829 (-\cx,-\cy) -- (0, 0) -- (1,0) -- (1-\cx,-\cy) -- cycle;
830 %% Left face (x)
831 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
832 (-\cx,-\cy) -- (-\cx,-\cy+1) -- (0,1) -- (0,0) -- cycle;
833 }
834 \newcommand{\DrawCubieLU}[3]{%
835 %% Front face (z)
836 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
837 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
838 %% Up face (y)
839 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
840 (-\cx,1+\cy) -- (1-\cx, 1+\cy) -- (1,1) -- (0,1) -- cycle;
841 %% Left face (x)
842 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
843 (-\cx, \cy) -- (-\cx,\cy+1) -- (0,1) -- (0,0) -- cycle;
844 }

```

17.15 Text cubies

`\textCubieRU` These four commands draw a single ‘text’ cubie from the RightUp, RightDown, `\textCubieRD` LeftUp, LeftDown viewpoint. They are ‘text’ forms of the `\DrawCubie` commands `\textCubieLU` described above. Their size was chosen to be suitable for use with 10–12 point `\textCubieLD` fonts.

As before, the viewpoint is specified using an appended two-letter XY ordered viewpoint code: either RU, RD, LU, LD. These commands take three arguments, namely three different XYZ ordered colour codes (R,O,Y,G,B,W,X).

FORMAT: `\textCubieRU{\langle Xcolour \rangle}{\langle Ycolour \rangle}{\langle Zcolour \rangle}`

USAGE: `\textCubieRU{G}{B}{W}`

```

845 \newcommand{\textCubieRU}[3]{%
846 \begin{minipage}{0.66cm}
847 \centering
848 \begin{tikzpicture}[scale=0.5]
849 \Cubiedx{0.4}\Cubiedy{0.4}
850 \DrawCubieRU{#1}{#2}{#3}
851 \end{tikzpicture}%

```



```

852 \end{minipage}
853 }
854 \newcommand{\textCubieRD}[3]{%
855 \begin{minipage}{0.66cm}
856 \centering
857 \begin{tikzpicture}[scale=0.5]
858 \Cubiedx{0.4}\Cubiedy{0.4}
859 \DrawCubieRD{#1}{#2}{#3}
860 \end{tikzpicture}%
861 \end{minipage}
862 }
863 \newcommand{\textCubieLD}[3]{%
864 \begin{minipage}{0.66cm}
865 \centering
866 \begin{tikzpicture}[scale=0.5]
867 \Cubiedx{0.4}\Cubiedy{0.4}
868 \DrawCubieLD{#1}{#2}{#3}
869 \end{tikzpicture}%
870 \end{minipage}
871 }
872 \newcommand{\textCubieLU}[3]{%
873 \begin{minipage}{0.66cm}
874 \centering
875 \begin{tikzpicture}[scale=0.5]
876 \Cubiedx{0.4}\Cubiedy{0.4}
877 \DrawCubieLU{#1}{#2}{#3}
878 \end{tikzpicture}%
879 \end{minipage}
880 }

```

17.16 Rotation commands

17.16.1 Introduction

We use a special prefix notation to denote each of four different representations of the various Rubik cube rotations as follows: the name of the rotation (rr), its associated hieroglyph (rrh), and combinations of name and hieroglyph both vertical (Rubik) and horizontal (textRubik). A rotation command is a combination of a rotation-code appended to one of the four prefixes.

For example, the command `\rrhD` generates the hieroglyph (rrh) associated with the rotation-code D. In this form it is used internally, but it is also available for the user. However, it is also made available to the user in the more intuitive form `\rrh{D}` by the use of the internal macro `\@join` (see Sections 17.16.2 and 17.2).

The square hieroglyphs are built up in stages. We first create an internal command for drawing the square (`\DrawNotationBox`), and then draw the contents (lines, arrows, arcs of circles, and sometimes just text). (for the TikZ ARC command see TikZ pgfmanual (2012) page 146 (§14.8)).

The presence of small overfilled `\hboxes` associated with these squares were originally checked using the `ltugboat.cls`, and all fixed mainly by setting the associated minipages $\rightarrow$ width = 0.6cm, and using TikZ scale=0.5.

`\DrawNotationBox` This internal command draws the surrounding square box of all the hieroglyphs. Note that we start at (0,0) and draw to the final point in order to make a nice corner join.

TODO: ? make this a proper internal command using @ sometime.

```
881 \newcommand{\DrawNotationBox}{%
882   \draw [thick] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0) -- (0,1)%
883 }
```

We now define a number of points and line-segments inside the square (e.g., `\@sd`, `\@sh` ... etc.) which will be required for use in drawing the various lines and arrows. Some hieroglyphs contain either one circular arc, or two concentric arcs, and these arcs require both a center and a start point. Note that the final argument does not use any units.

TODO: make a small diagram to illustrate the position of these parameters and make things a bit clearer sometime.

```
884 \pgfmathsetmacro{\@sd}{0.25} % a small horiz space
885 \pgfmathsetmacro{\@sdd}{2*\@sd} % 2x horiz space
886 \pgfmathsetmacro{\@sddd}{3*\@sd} % 3x horiz space
887 \pgfmathsetmacro{\@sh}{0.6} % height
888 \pgfmathsetmacro{\@sb}{0.2} % base
889 \pgfmathsetmacro{\@sbh}{\@sb + \@sh} % UP
890 \pgfmathsetmacro{\@scx}{\@sdd+0.2} % Start of CircleX arc
891 \pgfmathsetmacro{\@scy}{\@sd*2/3} % Start of CircleY arc
892 \pgfmathsetmacro{\@sqcx}{\@scx-0.13} %% Square CenterX coord
893 \pgfmathsetmacro{\@sqcy}{\@scy+0.25} %% Square CenterY cprd
```

All the @ internal commands used in the following commands and macros are described in Section 17.2.

17.16.2 Using `\join`

`\textRubik` The following four commands typeset a single rotation, where the rotation-code (eg U) is the argument (see Section 7.1). As an example, the format for the `\rrh{}`
`\Rubik` command is `\rrh{<rotation-code>}`. In practice, these four commands are really
`\rr` a sort of front-end for all the commands which follow this section. For example,
`\rrh` the command `\rrh{U}` generates the command `\rrhU` which itself typesets the rotation hieroglyph for the rotation U, etc.

These four commands, which use the internal `\@join` command (see Section 17.2), are especially useful when typesetting a list of rotation-codes. Furthermore, it seems more intuitive to specify a rotation command using the rotation-code as an argument.

```
894 \newcommand*{\Rubik}[1]{\@join{\Rubik}{#1}}
895 \newcommand*{\textRubik}[1]{\@join{\textRubik}{#1}}
```

```

896 \newcommand*{\rr}[1]{\@join{\rr}{#1}}
897 \newcommand*{\rrh}[1]{\@join{\rrh}{#1}}

```

17.16.3 Rotation B

`\rrB` These commands all draw forms which denote the B (BACK-face) rotation. Not visible from the front.

`\SquareB`

`\rrhB` 898 \newcommand{\rrB}{\@rr{B}}

`\RubikB` 899 \newcommand{\SquareB}{\@SquareLetter{\rrB}}

`\textRubikB` 900 \newcommand{\rrhB}{\raisebox{-0.25mm}{\SquareB}\,,}

901 \newcommand{\RubikB}{\raisebox{\@hRubik}{\SquareB}\,,}

902 \newcommand{\textRubikB}{\rrhB\,,}

17.16.4 Rotation Bp

`\rrBp` These commands all draw forms which denote the Bp rotation. Not visible from the front.

`\SquareBp`

`\rrhBp` 903 \newcommand{\rrBp}{\@rrp{B}}

`\RubikBp` 904 \newcommand{\SquareBp}{\@SquareLetter{\rrBp}}

`\textRubikBp` 905 \newcommand{\rrhBp}{\raisebox{-0.25mm}{\SquareBp}\,,}

906 \newcommand{\RubikBp}{\raisebox{\@hRubik}{\SquareBp}\,,}

907 \newcommand{\textRubikBp}{\rrhBp\,,}

17.16.5 Rotation Bw

`\rrBw` These commands all draw forms which denote the Bw rotation. Not visible from the front.

`\SquareBw`

`\rrhBw` 908 %\newcommand{\rrBw}{\textbf{\textsf{Bw}}}

`\RubikBw` 909 \newcommand{\rrBw}{\@rrw{B}}

`\textRubikBw` 910 \newcommand{\SquareBw}{\@SquareLetter{\rrBw}}

911 \newcommand{\rrhBw}{\raisebox{-0.25mm}{\SquareBw}\,,}

912 \newcommand{\RubikBw}{\raisebox{\@hRubik}{\SquareBw}\,,}

913 \newcommand{\textRubikBw}{\rrhBw\,,}

17.16.6 Rotation Bwp

`\rrBwp` These commands all draw forms which denote the Bwp rotation. Not visible from the front.

`\SquareBwp`

`\rrhBwp` 914 %\newcommand{\rrBwp}{\textbf{\textsf{Bwp}}}

`\RubikBwp` 915 \newcommand{\rrBwp}{\@rrwp{B}}

`\textRubikBwp` 916 \newcommand{\SquareBwp}{\@SquareLetter{\rrBwp}}

917 \newcommand{\rrhBwp}{\raisebox{-0.25mm}{\SquareBwp}\,,}

918 \newcommand{\RubikBwp}{\raisebox{\@hRubik}{\SquareBwp}\,,}

919 \newcommand{\textRubikBwp}{\rrhBwp\,,}

17.16.7 Rotation Bs

`\rrBs` These commands all draw forms which denote the Bs rotation. Not visible from
`\SquareBs` the front.
`\rrhBs` 920 `\newcommand{\rrBs}{\textbf{\textsf{Bs}}}`
`\RubikBs` 921 `\newcommand{\rrBs}{\@rrs{B}}`
`\textRubikBs` 922 `\newcommand{\SquareBs}{\@SquareLetter{\rrBs}}`
923 `\newcommand{\rrhBs}{\raisebox{-0.25mm}{\SquareBs}\,}`
924 `\newcommand{\RubikBs}{\raisebox{\@hRubik}{\SquareBs}\,}`
925 `\newcommand{\textRubikBs}{\rrhBs\,}`

17.16.8 Rotation Bsp

`\rrBsp` These commands all draw forms which denote the Bsp rotation. Not visible from
`\SquareBsp` the front.
`\rrhBsp` 926 `\newcommand{\rrBsp}{\textbf{\textsf{Bsp}}}`
`\RubikBsp` 927 `\newcommand{\rrBsp}{\@rrsp{B}}`
`\textRubikBsp` 928 `\newcommand{\SquareBsp}{\@SquareLetter{\rrBsp}}`
929 `\newcommand{\rrhBsp}{\raisebox{-0.25mm}{\SquareBsp}\,}`
930 `\newcommand{\RubikBsp}{\raisebox{\@hRubik}{\SquareBsp}\,}`
931 `\newcommand{\textRubikBsp}{\rrhBsp\,}`

17.16.9 Rotation Ba

`\rrBa` These commands all draw forms which denote the Ba rotation. Not visible from
`\SquareBa` the front.
`\rrhBa` 932 `\newcommand{\rrBa}{\textbf{\textsf{Ba}}}`
`\RubikBa` 933 `\newcommand{\rrBa}{\@rra{B}}`
`\textRubikBa` 934 `\newcommand{\SquareBa}{\@SquareLetter{\rrBa}}`
935 `\newcommand{\rrhBa}{\raisebox{-0.25mm}{\SquareBa}\,}`
936 `\newcommand{\RubikBa}{\raisebox{\@hRubik}{\SquareBa}\,}`
937 `\newcommand{\textRubikBa}{\rrhBa\,}`

17.16.10 Rotation Bap

`\rrBap` These commands all draw forms which denote the Bap rotation. Not visible from
`\SquareBap` the front.
`\rrhBap` 938 `\newcommand{\rrBap}{\textbf{\textsf{Bap}}}`
`\RubikBap` 939 `\newcommand{\rrBap}{\@rrap{B}}`
`\textRubikBap` 940 `\newcommand{\SquareBap}{\@SquareLetter{\rrBap}}`
941 `\newcommand{\rrhBap}{\raisebox{-0.25mm}{\SquareBap}\,}`
942 `\newcommand{\RubikBap}{\raisebox{\@hRubik}{\SquareBap}\,}`
943 `\newcommand{\textRubikBap}{\rrhBap\,}`

17.16.11 Rotation D

`\rrD` These commands all draw forms which denote the D rotation.
`\SquareD` 944 `\newcommand{\rrD}{\textbf{\textsf{D}}}`
`\rrhD`
`\RubikD`
`\textRubikD`

```

945 %%
946 \newcommand{\SquareD}{%
947 \begin{tikzpicture}[scale=0.5]
948 \DrawNotationBox;
949 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
950 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
951 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
952 \end{tikzpicture}%
953 }
954 \newcommand{\rrhD}{\raisebox{-0.333\height}{\SquareD}\,,}
955 %%
956 \newcommand{\RubikD}{%
957 \begin{minipage}{0.6cm}
958 \centering
959 \SquareD\
960 \rrD
961 \end{minipage}%
962 }
963 \newcommand{\textRubikD}{\rrD\,,\rrhD}

```

17.16.12 Rotation Dp

`\rrDp` These commands all draw forms which denote the Dp rotation.

`\SquareDp` 964 \newcommand{\rrDp}{\textbf{\textsf{D}\$^{\prime}\$}}

`\rrhDp` 965 %%

`\RubikDp` 966 \newcommand{\SquareDp}{%

`\textRubikDp` 967 \begin{tikzpicture}[scale=0.5]

968 \DrawNotationBox;

969 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);

970 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);

971 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);

972 \end{tikzpicture}%

973 }

974 \newcommand{\rrhDp}{\raisebox{-0.333\height}{\SquareDp}\,,}

975 %%

976 \newcommand{\RubikDp}{%

977 \begin{minipage}{0.6cm}

978 \centering

979 \SquareDp\

980 \rrDp

981 \end{minipage}%

982 }

983 \newcommand{\textRubikDp}{\rrDp\,,\rrhDp}

17.16.13 Rotation Dw

`\rrDw` These commands all draw forms which denote the Dw rotation.

`\SquareDw` 984 \newcommand{\rrDw}{\textbf{\textsf{D}\footnotesize{w}}}

`\rrhDw` 985 %%

`\RubikDw`

`\textRubikDw`

```

986 \newcommand{\SquareDw}{%
987 \begin{tikzpicture}[scale=0.5]
988 \DrawNotationBox;
989 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
990 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
991 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
992 \end{tikzpicture}%
993 }
994 \newcommand{\rrhDw}{\raisebox{-0.333\height}{\SquareDw}\,,}
995 %%
996 \newcommand{\RubikDw}{%
997 \begin{minipage}{0.6cm}
998 \centering
999 \SquareDw\\
1000 \rrDw
1001 \end{minipage}%
1002 }
1003 \newcommand{\textRubikDw}{\rrDw\,,\rrhDw}

```

17.16.14 Rotation Dwp

\rrDwp These commands all draw forms which denote the Dwp rotation.

```

\SquareDwp 1004 \newcommand{\rrDwp}{\textbf{\textsf{D}\footnotesize{w}}$\sim\prime$}}
\rrhDwp 1005 %%
\RubikDwp 1006 \newcommand{\SquareDwp}{%
\textRubikDwp 1007 \begin{tikzpicture}[scale=0.5]
1008 \DrawNotationBox;
1009 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1010 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1011 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1012 \end{tikzpicture}%
1013 }
1014 \newcommand{\rrhDwp}{\raisebox{-0.333\height}{\SquareDwp}\,,}
1015 %%
1016 \newcommand{\RubikDwp}{%
1017 \begin{minipage}{0.6cm}
1018 \centering
1019 \SquareDwp\\
1020 \rrDwp
1021 \end{minipage}%
1022 }
1023 \newcommand{\textRubikDwp}{\rrDwp\,,\rrhDwp}

```

17.16.15 Rotation Ds

\rrDs These commands all draw forms which denote the Ds rotation.

```

\SquareDs 1024 \newcommand{\rrDs}{\@rrs{D}}
\rrhDs 1025 %%
\RubikDs 1026 \newcommand{\SquareDs}{%
\textRubikDs

```

```

1027 \begin{tikzpicture}[scale=0.5]
1028 \DrawNotationBox;
1029 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1030 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1031 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1032 \end{tikzpicture}%
1033 }
1034 \newcommand{\rrhDs}{\raisebox{-0.333\height}{\SquareDs}\,,}
1035 %%
1036 \newcommand{\RubikDs}{%
1037 \begin{minipage}{0.6cm}
1038 \centering
1039 \SquareDs\
1040 \rrDs
1041 \end{minipage}%
1042 }
1043 \newcommand{\textRubikDs}{\rrDs\,,\rrhDs}

```

17.16.16 Rotation Dsp

`\rrDsp` These commands all draw forms which denote the Dsp rotation.

```

\SquareDsp 1044 \newcommand{\rrDsp}{\@rrsp{D}}
\rrhDsp 1045 %%
\RubikDsp 1046 \newcommand{\SquareDsp}{%
\textRubikDsp 1047 \begin{tikzpicture}[scale=0.5]
1048 \DrawNotationBox;
1049 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1050 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1051 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1052 \end{tikzpicture}%
1053 }
1054 \newcommand{\rrhDsp}{\raisebox{-0.333\height}{\SquareDsp}\,,}
1055 %%
1056 \newcommand{\RubikDsp}{%
1057 \begin{minipage}{0.6cm}
1058 \centering
1059 \SquareDsp\
1060 \rrDsp
1061 \end{minipage}%
1062 }
1063 \newcommand{\textRubikDsp}{\rrDsp\,,\rrhDsp}

```

17.16.17 Rotation Da

`\rrDa` These commands all draw forms which denote the Da rotation.

```

\SquareDa 1064 \newcommand{\rrDa}{\@rra{D}}
\rrhDa 1065 %%
\RubikDa 1066 \newcommand{\SquareDa}{%
\textRubikDa 1067 \begin{tikzpicture}[scale=0.5]

```

```

1068 \DrawNotationBox;
1069 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1070 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1071 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1072 \end{tikzpicture}%
1073 }
1074 \newcommand{\rrhDa}{\raisebox{-0.333\height}{\SquareDa}\,,}
1075 %%
1076 \newcommand{\RubikDa}{%
1077 \begin{minipage}{0.6cm}
1078 \centering
1079 \SquareDa\\
1080 \rrDa
1081 \end{minipage}%
1082 }
1083 \newcommand{\textRubikDa}{\rrDa\,,\rrhDa}

```

17.16.18 Rotation Dap

`\rrDap` These commands all draw forms which denote the Dap rotation.

```

\SquareDap 1084 \newcommand{\rrDap}{\@rrap{D}}
\rrhDap 1085 %%
\RubikDap 1086 \newcommand{\SquareDap}{%
\textRubikDap 1087 \begin{tikzpicture}[scale=0.5]
1088 \DrawNotationBox;
1089 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1090 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1091 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1092 \end{tikzpicture}%
1093 }
1094 \newcommand{\rrhDap}{\raisebox{-0.333\height}{\SquareDap}\,,}
1095 %%
1096 \newcommand{\RubikDap}{%
1097 \begin{minipage}{0.6cm}
1098 \centering
1099 \SquareDap\\
1100 \rrDap
1101 \end{minipage}%
1102 }
1103 \newcommand{\textRubikDap}{\rrDap\,,\rrhDap}

```

17.16.19 Rotation E

`\rrE` These commands all draw forms which denote the E rotation.

```

\SquareE 1104 \newcommand{\rrE}{\textbf{\textsf{E}}}
\rrhE 1105 %%
\RubikE 1106 \newcommand{\SquareE}{%
\textRubikE 1107 \begin{tikzpicture}[scale=0.5]
1108 \DrawNotationBox;

```



```

1109 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1110 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1111 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1112 \end{tikzpicture}%
1113 }
1114 \newcommand{\rrhE}{\raisebox{-0.333\height}{\SquareE}\,,}
1115 %%
1116 \newcommand{\RubikE}{%
1117 \begin{minipage}{0.6cm}
1118 \centering
1119 \SquareE\
1120 \rrE
1121 \end{minipage}%
1122 }
1123 \newcommand{\textRubikE}{\rrE\,,\rrhE}

```

17.16.20 Rotation Ep

`\rrEp` These commands all draw forms which denote the Ep rotation.

```

\SquareEp 1124 \newcommand{\rrEp}{\textbf{\textsf{E}}$^{\prime}$}
\rrhEp    1125 %%
\RubikEp  1126 \newcommand{\SquareEp}{%
\textRubikEp 1127 \begin{tikzpicture}[scale=0.5]
1128 \DrawNotationBox;
1129 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1130 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1131 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1132 \end{tikzpicture}%
1133 }
1134 \newcommand{\rrhEp}{\raisebox{-0.333\height}{\SquareEp}\,,}
1135 %%
1136 \newcommand{\RubikEp}{%
1137 \begin{minipage}{0.6cm}
1138 \centering
1139 \SquareEp\
1140 \rrEp
1141 \end{minipage}%
1142 }
1143 \newcommand{\textRubikEp}{\rrEp\,,\rrhEp}

```

17.16.21 Rotation F

`\rrF` These commands all draw forms which denote the F rotation.

```

\SquareF 1144 \newcommand{\rrF}{\textbf{\textsf{F}}}
\rrhF    1145 %%
\RubikF  1146 \newcommand{\SquareF}{%
\textRubikF 1147 \begin{tikzpicture}[scale=0.5]
1148 \DrawNotationBox;
1149 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];

```

```

1150 \end{tikzpicture}%
1151 }
1152 \newcommand{\rrhF}{\raisebox{-0.333\height}{\SquareF}\,,}
1153 %%
1154 \newcommand{\RubikF}{%
1155 \begin{minipage}{0.6cm}
1156 \centering
1157 \SquareF\
1158 \rrF
1159 \end{minipage}%
1160 }
1161 \newcommand{\textRubikF}{\rrF\,,\rrhF}

```

17.16.22 Rotation Fp

`\rrFp` These commands all draw forms which denote the Fp rotation.

```

\SquareFp 1162 \newcommand{\rrFp}{\textbf{\textsf{F}}$^\prime$}
\rrhFp    1163 %%
\RubikFp  1164 \newcommand{\SquareFp}{%
\textRubikFp 1165 \begin{tikzpicture}[scale=0.5]
1166 \DrawNotationBox;
1167 \draw [thick, ->] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1168 \end{tikzpicture}%
1169 }
1170 \newcommand{\rrhFp}{\raisebox{-0.333\height}{\SquareFp}\,,}
1171 %%
1172 \newcommand{\RubikFp}{%
1173 \begin{minipage}{0.6cm}
1174 \centering
1175 \SquareFp\
1176 \rrFp
1177 \end{minipage}%
1178 }
1179 \newcommand{\textRubikFp}{\rrFp\,,\rrhFp}

```

17.16.23 Rotation Fw

`\rrFw` These commands all draw forms which denote the Fw rotation.

```

\SquareFw 1180 \newcommand{\rrFw}{\textbf{\textsf{F}}\footnotesize{w}}
\rrhFw    1181 %%
\RubikFw  1182 \newcommand{\SquareFw}{%
\textRubikFw 1183 \begin{tikzpicture}[scale=0.5]
1184 \DrawNotationBox;
1185 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1186 \draw [thick] (\@sqcx,\@sqcy) arc[radius=0.1, start angle=-60, delta angle=360];
1187 %\node (squareLab) at (0.5,0.5) {\$o\$};
1188 \end{tikzpicture}%
1189 }
1190 \newcommand{\rrhFw}{\raisebox{-0.333\height}{\SquareFw}\,,}

```

```

1191 %%
1192 \newcommand{\RubikFw}{%
1193 \begin{minipage}{0.6cm}
1194 \centering
1195 \SquareFw\
1196 \rrFw
1197 \end{minipage}%
1198 }
1199 \newcommand{\textRubikFw}{\rrFw\,\rrhFw}

```

17.16.24 Rotation Fwp

`\rrFwp` These commands all draw forms which denote the Fwp rotation.

`\SquareFwp` 1200 \newcommand{\rrFwp}{\textbf{\textsf{F}\footnotesize{w}}\$^\prime\$}}

`\rrhFwp` 1201 %%

`\RubikFwp` 1202 \newcommand{\SquareFwp}{%

`\textRubikFwp` 1203 \begin{tikzpicture}[scale=0.5]

1204 \DrawNotationBox;

1205 \draw [thick, ->] (@scx, @scy) arc[radius=0.35, start angle=-60, delta angle=290];

1206 \draw [thick] (@sqcx, @sqcy) arc[radius=0.1, start angle=-60, delta angle=360];

1207 \end{tikzpicture}%

1208 }

1209 \newcommand{\rrhFwp}{\raisebox{-0.333\height}{\SquareFwp}\,,}

1210 %%

1211 \newcommand{\RubikFwp}{%

1212 \begin{minipage}{0.6cm}

1213 \centering

1214 \SquareFwp\

1215 \rrFwp

1216 \end{minipage}%

1217 }

1218 \newcommand{\textRubikFwp}{\rrFwp\,\rrhFwp}

1219 %%

17.16.25 Rotation Fs

`\rrFs` These commands draw forms of the Singmaster Fs slice rotation. We need to just

`\rrhFs` make square with Fs in square; adjust box height using a `\rule`; adjust `\fboxsep`

`\RubikFs` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to

`\textRubikFs` reset to defaults. Not visible from the front.

1220 \newcommand{\rrFs}{\@rrs{F}}

1221 \newcommand{\SquareFs}{\@SquareLetter{\rrFs}}

1222 \newcommand{\rrhFs}{\raisebox{-0.25mm}{\SquareFs}\,,}

1223 \newcommand{\RubikFs}{\raisebox{\@hRubik}{\SquareFs}\,,}

1224 \newcommand{\textRubikFs}{\rrhFs\,,}

17.16.26 Rotation Fsp

`\rrFsp` These commands draw forms of the Singmaster Fsp slice rotation. We need to
`\rrhFsp` just make square with Fsp in square; adjust box height using a `\rule`; adjust
`\RubikFsp` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikFsp` need to reset to defaults. Not visible from the front.

```

1225 \newcommand{\rrFsp}{\@rrsp{F}}
1226 \newcommand{\SquareFsp}{\@SquareLetter{\rrFsp}}
1227 \newcommand{\rrhFsp}{\raisebox{-0.25mm}{\SquareFsp}\,}
1228 \newcommand{\RubikFsp}{\raisebox{\@hRubik}{\SquareFsp}\,}
1229 \newcommand{\textRubikFsp}{\rrhFsp\,}

```

17.16.27 Rotation Fa

`\rrFa` These commands draw forms of the Singmaster Fa slice rotation. We need to just
`\rrhFa` make square with Fa in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikFa` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikFa` reset to defaults. Not visible from the front.

```

1230 \newcommand{\rrFa}{\@rra{F}}
1231 \newcommand{\SquareFa}{\@SquareLetter{\rrFa}}
1232 \newcommand{\rrhFa}{\raisebox{-0.25mm}{\SquareFa}\,}
1233 \newcommand{\RubikFa}{\raisebox{\@hRubik}{\SquareFa}\,}
1234 \newcommand{\textRubikFa}{\rrhFa\,}

```

17.16.28 Rotation Fap

`\rrFap` These commands draw forms of the Singmaster Fap slice rotation. We need to
`\rrhFap` just make square with Fap in square; adjust box height using a `\rule`; adjust
`\RubikFap` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikFap` need to reset to defaults. Not visible from the front.

```

1235 \newcommand{\rrFap}{\@rrap{F}}
1236 \newcommand{\SquareFap}{\@SquareLetter{\rrFap}}
1237 \newcommand{\rrhFap}{\raisebox{-0.25mm}{\SquareFap}\,}
1238 \newcommand{\RubikFap}{\raisebox{\@hRubik}{\SquareFap}\,}
1239 \newcommand{\textRubikFap}{\rrhFap\,}

```

17.16.29 Rotation L

`\rrL` These commands all draw forms which denote the L rotation.

```

\SquareL 1240 \newcommand{\rrL}{\textbf{\textsf{L}}}
\rrhL    1241 %%
\RubikL  1242 \newcommand{\SquareL}{%
\textRubikL 1243 \begin{tikzpicture}[scale=0.5]
1244 \DrawNotationBox;
1245 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1246 \draw [thick] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1247 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1248 \end{tikzpicture}%

```

```

1249 }
1250 \newcommand{\rrhL}{\raisebox{-0.333\height}{\SquareL}\,}
1251 %%
1252 \newcommand{\RubikL}{%
1253 \begin{minipage}{0.6cm}
1254 \centering
1255 \SquareL\
1256 \rrL
1257 \end{minipage}%
1258 }
1259 \newcommand{\textRubikL}{\rrL\,\rrhL}

```

17.16.30 Rotation Lp

`\rrLp` These commands all draw forms which denote the Lp rotation.

```

\SquareLp 1260 \newcommand{\rrLp}{\textbf{\textsf{L}}$^\prime$}
\rrhLp    1261 %%
\RubikLp  1262 \newcommand{\SquareLp}{%
\textRubikLp 1263 \begin{tikzpicture}[scale=0.5]
1264 \DrawNotationBox;
1265 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1266 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1267 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1268 \end{tikzpicture}%
1269 }
1270 \newcommand{\rrhLp}{\raisebox{-0.333\height}{\SquareLp}\,}
1271 %%
1272 \newcommand{\RubikLp}{%
1273 \begin{minipage}{0.6cm}
1274 \centering
1275 \SquareLp\
1276 \rrLp
1277 \end{minipage}%
1278 }
1279 \newcommand{\textRubikLp}{\rrLp\,\rrhLp}

```

17.16.31 Rotation Lw

`\rrLw` These commands all draw forms which denote the Lw rotation.

```

\SquareLw 1280 \newcommand{\rrLw}{\textbf{\textsf{L}}\footnotesize{w}}
\rrhLw    1281 %%
\RubikLw  1282 \newcommand{\SquareLw}{%
\textRubikLw 1283 \begin{tikzpicture}[scale=0.5]
1284 \DrawNotationBox;
1285 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1286 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1287 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1288 \end{tikzpicture}%
1289 }

```

```

1290 \newcommand{\rrhLw}{\raisebox{-0.333\height}{\SquareLw}\,}
1291 %%
1292 \newcommand{\RubikLw}{%
1293 \begin{minipage}{0.6cm}
1294 \centering
1295 \SquareLw\
1296 \rrLw
1297 \end{minipage}%
1298 }
1299 \newcommand{\textRubikLw}{\rrLw\,\rrhLw}

```

17.16.32 Rotation Lwp

`\rrLwp` These commands all draw forms which denote the Lwp rotation.

```

\SquareLwp 1300 \newcommand{\rrLwp}{\textbf{\textsf{L}\footnotesize{w}}$\prime$}
\rrhLwp    1301 %%
\RubikLwp  1302 \newcommand{\SquareLwp}{%
\textRubikLwp 1303 \begin{tikzpicture}[scale=0.5]
1304 \DrawNotationBox;
1305 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1306 \draw [thick,->] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1307 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1308 \end{tikzpicture}%
1309 }
1310 \newcommand{\rrhLwp}{\raisebox{-0.333\height}{\SquareLwp}\,}
1311 %%
1312 \newcommand{\RubikLwp}{%
1313 \begin{minipage}{0.6cm}
1314 \centering
1315 \SquareLwp\
1316 \rrLwp
1317 \end{minipage}%
1318 }
1319 \newcommand{\textRubikLwp}{\rrLwp\,\rrhLwp}

```

17.16.33 Rotation Ls

`\rrLs` These commands all draw forms which denote the Ls rotation.

```

\SquareLs 1320 \newcommand{\rrLs}{\@rrs{L}}
\rrhLs    1321 %%
\RubikLs  1322 \newcommand{\SquareLs}{%
\textRubikLs 1323 \begin{tikzpicture}[scale=0.5]
1324 \DrawNotationBox;
1325 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1326 \draw [thick] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1327 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1328 \end{tikzpicture}%
1329 }
1330 \newcommand{\rrhLs}{\raisebox{-0.333\height}{\SquareLs}\,}

```

```

1331 %%
1332 \newcommand{\RubikLs}{%
1333 \begin{minipage}{0.6cm}
1334 \centering
1335 \SquareLs\
1336 \rrLs
1337 \end{minipage}%
1338 }
1339 \newcommand{\textRubikLs}{\rrLs\,\rrhLs}

```

17.16.34 Rotation Lsp

\rrLsp These commands all draw forms which denote the Lsp rotation.

```

\SquareLsp 1340 \newcommand{\rrLsp}{\@rrsp{L}}
\rrhLsp    1341 %%
\RubikLsp  1342 \newcommand{\SquareLsp}{%
\textRubikLsp 1343 \begin{tikzpicture}[scale=0.5]
1344 \DrawNotationBox;
1345 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1346 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1347 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1348 \end{tikzpicture}%
1349 }
1350 \newcommand{\rrhLsp}{\raisebox{-0.333\height}{\SquareLsp}\,,}
1351 %%
1352 \newcommand{\RubikLsp}{%
1353 \begin{minipage}{0.6cm}
1354 \centering
1355 \SquareLsp\
1356 \rrLsp
1357 \end{minipage}%
1358 }
1359 \newcommand{\textRubikLsp}{\rrLsp\,\rrhLsp}

```

17.16.35 Rotation La

\rrLa These commands all draw forms which denote the La rotation.

```

\SquareLa 1360 \newcommand{\rrLa}{\@rra{L}}
\rrhLa    1361 %%
\RubikLa  1362 \newcommand{\SquareLa}{%
\textRubikLa 1363 \begin{tikzpicture}[scale=0.5]
1364 \DrawNotationBox;
1365 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1366 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1367 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1368 \end{tikzpicture}%
1369 }
1370 \newcommand{\rrhLa}{\raisebox{-0.333\height}{\SquareLa}\,,}
1371 %%

```

```

1372 \newcommand{\RubikLa}{%
1373 \begin{minipage}{0.6cm}
1374 \centering
1375 \SquareLa\
1376 \rrLa
1377 \end{minipage}%
1378 }
1379 \newcommand{\textRubikLa}{\rrLa\,\rrhLa}

```

17.16.36 Rotation Lap

`\rrLap` These commands all draw forms which denote the Lap rotation.

```

\SquareLap 1380 \newcommand{\rrLap}{\@rrap{L}}
\rrhLap 1381 %%
\RubikLap 1382 \newcommand{\SquareLap}{%
\textRubikLap 1383 \begin{tikzpicture}[scale=0.5]
1384 \DrawNotationBox;
1385 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1386 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1387 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1388 \end{tikzpicture}%
1389 }
1390 \newcommand{\rrhLap}{\raisebox{-0.333\height}{\SquareLap}\,,}
1391 %%
1392 \newcommand{\RubikLap}{%
1393 \begin{minipage}{0.6cm}
1394 \centering
1395 \SquareLap\
1396 \rrLap
1397 \end{minipage}%
1398 }
1399 \newcommand{\textRubikLap}{\rrLap\,\rrhLap}

```

17.16.37 Rotation M

`\rrM` These commands all draw forms which denote the M rotation.

```

\SquareM 1400 \newcommand{\rrM}{\textbf{\textsf{M}}}
\rrhM 1401 %%
\RubikM 1402 \newcommand{\SquareM}{%
\textRubikM 1403 \begin{tikzpicture}[scale=0.5]
1404 \DrawNotationBox;
1405 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1406 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1407 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1408 \end{tikzpicture}%
1409 }
1410 \newcommand{\rrhM}{\raisebox{-0.333\height}{\SquareM}\,,}
1411 %%
1412 \newcommand{\RubikM}{%

```



```

1413 \begin{minipage}{0.6cm}
1414 \centering
1415 \SquareM\
1416 \rrM
1417 \end{minipage}%
1418 }
1419 \newcommand{\textRubikM}{\rrM\,\rrhM}

```

17.16.38 Rotation Mp

\rrMp These commands all draw forms which denote the Mp rotation.

```

\SquareMp 1420 \newcommand{\rrMp}{\textbf{\textsf{M}}$^{\prime}$}
\rrhMp    1421 %%
\RubikMp  1422 \newcommand{\SquareMp}{%
\textRubikMp 1423 \begin{tikzpicture}[scale=0.5]
1424 \DrawNotationBox;
1425 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1426 \draw [thick,->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1427 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1428 \end{tikzpicture}%
1429 }
1430 \newcommand{\rrhMp}{\raisebox{-0.333\height}{\SquareMp}\,,}
1431 %%
1432 \newcommand{\RubikMp}{%
1433 \begin{minipage}{0.6cm}
1434 \centering
1435 \SquareMp\
1436 \rrMp
1437 \end{minipage}%
1438 }
1439 \newcommand{\textRubikMp}{\rrMp\,\rrhMp}

```

17.16.39 Rotation R

\rrR These commands all draw forms which denote the R rotation.

```

\SquareR 1440 \newcommand{\rrR}{\textbf{\textsf{R}}}
\rrhR    1441 %%
\RubikR  1442 \newcommand{\SquareR}{%
\textRubikR 1443 \begin{tikzpicture}[scale=0.5]
1444 \DrawNotationBox;
1445 %% draw three lines in the square, one with an arrow
1446 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1447 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1448 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1449 \end{tikzpicture}%
1450 }
1451 \newcommand{\rrhR}{\raisebox{-0.333\height}{\SquareR}\,,}
1452 %%
1453 \newcommand{\RubikR}{%

```

```

1454 \begin{minipage}{0.6cm}
1455 \centering
1456 \SquareR\
1457 \rrR
1458 \end{minipage}%
1459 }
1460 \newcommand{\textRubikR}{\rrR\,\rrhR}

```

17.16.40 Rotation Rp

`\rrRp` These commands all draw forms which denote the Rp rotation.

```

\SquareRp 1461 \newcommand{\rrRp}{\textbf{\textsf{R}}$^{\prime}$}
\rrhRp    1462 %%
\RubikRp  1463 \newcommand{\SquareRp}{%
\textRubikRp 1464 \begin{tikzpicture}[scale=0.5]
1465 \DrawNotationBox;
1466 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1467 \draw [thick] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1468 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1469 \end{tikzpicture}%
1470 }
1471 \newcommand{\rrhRp}{\raisebox{-0.333\height}{\SquareRp}\,,}
1472 %%
1473 \newcommand{\RubikRp}{%
1474 \begin{minipage}{0.6cm}
1475 \centering
1476 \SquareRp\
1477 \rrRp
1478 \end{minipage}%
1479 }
1480 \newcommand{\textRubikRp}{\rrRp\,\rrhRp}

```

17.16.41 Rotation Rw

`\rrRw` These commands all draw forms which denote the Rw rotation.

```

\SquareRw 1481 \newcommand{\rrRw}{\textbf{\textsf{R}}\footnotesize{w}}
\rrhRw    1482 %%
\RubikRw  1483 \newcommand{\SquareRw}{%
\textRubikRw 1484 \begin{tikzpicture}[scale=0.5]
1485 \DrawNotationBox;
1486 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1487 \draw [thick, ->] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1488 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1489 \end{tikzpicture}%
1490 }
1491 \newcommand{\rrhRw}{\raisebox{-0.333\height}{\SquareRw}\,,}
1492 %%
1493 \newcommand{\RubikRw}{%
1494 \begin{minipage}{0.6cm}

```

```

1495 \centering
1496 \SquareRw\\
1497 \rrRw
1498 \end{minipage}%
1499 }
1500 \newcommand{\textRubikRw}{\rrRw\,\rrhRw}

```

17.16.42 Rotation Rwp

\rrRwp These commands all draw forms which denote the Rwp rotation.

```

\SquareRwp 1501 \newcommand{\rrRwp}{\textbf{\textsf{R}\footnotesize{w}}$\prime$}
\rrhRwp 1502 %%
\RubikRwp 1503 \newcommand{\SquareRwp}{%
\textRubikRwp 1504 \begin{tikzpicture}[scale=0.5]
1505 \DrawNotationBox;
1506 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1507 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1508 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1509 \end{tikzpicture}%
1510 }
1511 \newcommand{\rrhRwp}{\raisebox{-0.333\height}{\SquareRwp}\,,}
1512 %%
1513 \newcommand{\RubikRwp}{%
1514 \begin{minipage}{0.6cm}
1515 \centering
1516 \SquareRwp\\
1517 \rrRwp
1518 \end{minipage}%
1519 }
1520 \newcommand{\textRubikRwp}{\rrRwp\,\rrhRwp}

```

17.16.43 Rotation Rs

\rrRs These commands all draw forms which denote the Rs rotation.

```

\SquareRs 1521 \newcommand{\rrRs}{\@rrs{R}}
\rrhRs 1522 %%
\RubikRs 1523 \newcommand{\SquareRs}{%
\textRubikRs 1524 \begin{tikzpicture}[scale=0.5]
1525 \DrawNotationBox;
1526 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1527 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1528 \draw [thick,->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1529 \end{tikzpicture}%
1530 }
1531 \newcommand{\rrhRs}{\raisebox{-0.333\height}{\SquareRs}\,,}
1532 %%
1533 \newcommand{\RubikRs}{%
1534 \begin{minipage}{0.6cm}
1535 \centering

```

```

1536 \SquareRs\
1537 \rrRs
1538 \end{minipage}%
1539 }
1540 \newcommand{\textRubikRs}{\rrRs\,\rrhRs}

```

17.16.44 Rotation Rsp

\rrRsp These commands all draw forms which denote the Rsp rotation.

```

\SquareRsp 1541 \newcommand{\rrRsp}{\@rrsp{R}}
\rrhRsp    1542 %%
\RubikRsp  1543 \newcommand{\SquareRsp}{%
\textRubikRsp 1544 \begin{tikzpicture}[scale=0.5]
1545 \DrawNotationBox;
1546 \draw [thick,<-] (@sd, @sb) -- (@sd, @sbh);
1547 \draw [thick] (@sdd,@sb) -- (@sdd, @sbh);
1548 \draw [thick,<-] (@sddd, @sb) -- (@sddd, @sbh);
1549 \end{tikzpicture}%
1550 }
1551 \newcommand{\rrhRsp}{\raisebox{-0.333\height}{\SquareRsp}\,,}
1552 %%
1553 \newcommand{\RubikRsp}{%
1554 \begin{minipage}{0.6cm}
1555 \centering
1556 \SquareRsp\
1557 \rrRsp
1558 \end{minipage}%
1559 }
1560 \newcommand{\textRubikRsp}{\rrRsp\,\rrhRsp}

```

17.16.45 Rotation Ra

\rrRa These commands all draw forms which denote the Ra rotation.

```

\SquareRa 1561 \newcommand{\rrRa}{\@rra{R}}
\rrhRa    1562 %%
\RubikRa  1563 \newcommand{\SquareRa}{%
\textRubikRa 1564 \begin{tikzpicture}[scale=0.5]
1565 \DrawNotationBox;
1566 \draw [thick,<-] (@sd, @sb) -- (@sd, @sbh);
1567 \draw [thick] (@sdd,@sb) -- (@sdd, @sbh);
1568 \draw [thick,->] (@sddd, @sb) -- (@sddd, @sbh);
1569 \end{tikzpicture}%
1570 }
1571 \newcommand{\rrhRa}{\raisebox{-0.333\height}{\SquareRa}\,,}
1572 %%
1573 \newcommand{\RubikRa}{%
1574 \begin{minipage}{0.6cm}
1575 \centering
1576 \SquareRa\

```

```

1577 \rrRa
1578 \end{minipage}%
1579 }
1580 \newcommand{\textRubikRa}{\rrRa\,\rrhRa}

```

17.16.46 Rotation Rap

`\rrRap` These commands all draw forms which denote the Rap rotation.

```

\SquareRap 1581 \newcommand{\rrRap}{\@rrap{R}}
\rrhRap 1582 %%
\RubikRap 1583 \newcommand{\SquareRap}{%
\textRubikRap 1584 \begin{tikzpicture}[scale=0.5]
1585 \DrawNotationBox;
1586 \draw [thick,->] (@sd, @sb) -- (@sd, @sbh);
1587 \draw [thick] (@sdd, @sb) -- (@sdd, @sbh);
1588 \draw [thick,<-] (@sddd, @sb) -- (@sddd, @sbh);
1589 \end{tikzpicture}%
1590 }
1591 \newcommand{\rrhRap}{\raisebox{-0.333\height}{\SquareRap}\,,}
1592 %%
1593 \newcommand{\RubikRap}{%
1594 \begin{minipage}{0.6cm}
1595 \centering
1596 \SquareRap\,
1597 \rrRap
1598 \end{minipage}%
1599 }
1600 \newcommand{\textRubikRap}{\rrRap\,\rrhRap}

```

17.16.47 Rotation S

`\rrS` These commands all draw forms which denote the S rotation. Not visible from the front.

```

\rrhS 1601 \newcommand{\rrS}{\@rr{S}}
\RubikS 1602 \newcommand{\SquareS}{\@SquareLetter{\rrS}}
\textRubikS 1603 \newcommand{\rrhS}{\raisebox{-0.25mm}{\SquareS}\,,}
1604 \newcommand{\RubikS}{\raisebox{\@hRubik}{\SquareS}\,,}
1605 \newcommand{\textRubikS}{\rrhS\,,}

```

17.16.48 Rotation Sp

`\rrSp` These commands all draw forms which denote the Sp rotation. Not visible from the front.

```

\rrhSp 1606 \newcommand{\rrSp}{\@rrp{S}}
\RubikSp 1607 \newcommand{\SquareSp}{\@SquareLetter{\rrSp}}
\textRubikSp 1608 \newcommand{\rrhSp}{\raisebox{-0.25mm}{\SquareSp}\,,}
1609 \newcommand{\RubikSp}{\raisebox{\@hRubik}{\SquareSp}\,,}
1610 \newcommand{\textRubikSp}{\rrhSp\,,}

```

17.16.49 Rotation Su

`\rrSu` These commands draw forms of the Singmaster Su slice rotation. We also need to
`\rrhSu` finetune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
`\RubikSu` 1611 `\newcommand{\rrSu}{\textbf{\textsf{S\footnotesize{u}}}}`
`\textRubikSu` 1612 `\newcommand{\rrhSu}{\rrhEp}%`
1613 `\newcommand{\RubikSu}{%`
1614 `\begin{minipage}{0.6cm}`
1615 `\centering`
1616 `\SquareEp\`
1617 `\rrSu`
1618 `\end{minipage}%`
1619 `}`
1620 `\newcommand{\textRubikSu}{\rrSu\,\rrhEp}`

17.16.50 Rotation Sup

`\rrSup` These commands draw forms of the Singmaster Sup slice rotation. We also need
`\rrhSup` to finetune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
`\RubikSup` 1621 `\newcommand{\rrSup}{\textbf{\textsf{S\footnotesize{u}}}$\sim\prime$}}`
`\textRubikSup` 1622 `\newcommand{\rrhSup}{\rrhE}%`
1623 `\newcommand{\RubikSup}{%`
1624 `\begin{minipage}{0.6cm}`
1625 `\centering`
1626 `\SquareE\`
1627 `\rrSup`
1628 `\end{minipage}%`
1629 `}`
1630 `\newcommand{\textRubikSup}{\rrSup\,\rrhE}`

17.16.51 Rotation Sd

`\rrSd` These commands draw forms of the Singmaster Sd slice rotation.
`\rrhSd` 1631 `\newcommand{\rrSd}{\textbf{\textsf{S\footnotesize{d}}}}`
`\RubikSd` 1632 `\newcommand{\rrhSd}{\rrhE}%`
`\textRubikSd` 1633 `\newcommand{\RubikSd}{%`
1634 `\begin{minipage}{0.6cm}`
1635 `\centering`
1636 `\SquareE\`
1637 `\rrSd`
1638 `\end{minipage}%`
1639 `}`
1640 `\newcommand{\textRubikSd}{\rrSd\,\rrhE}`

17.16.52 Rotation Sdp

`\rrSdp` These commands draw forms of the Singmaster Sdp slice rotation.
`\rrhSdp` 1641 `\newcommand{\rrSdp}{\textbf{\textsf{S\footnotesize{d}}}$\sim\prime$}}`
`\RubikSdp` 1642 `\newcommand{\rrhSdp}{\rrhEp}%`
`\textRubikSdp`

```

1643 \newcommand{\RubikSdp}{%
1644 \begin{minipage}{0.6cm}
1645 \centering
1646 \SquareEp\\
1647 \rrSdp
1648 \end{minipage}%
1649 }
1650 \newcommand{\textRubikSdp}{\rrSdp\,\rrhEp}

```

17.16.53 Rotation Sl

`\rrSl` These commands draw forms of the Singmaster Sl slice rotation.

```

\rrhSl 1651 \newcommand{\rrSl}{\textbf{\textsf{S\footnotesize{1}}}}
\RubikSl 1652 \newcommand{\rrhSl}{\rrhM}%
\textRubikSl 1653 \newcommand{\RubikSl}{%
1654 \begin{minipage}{0.6cm}
1655 \centering
1656 \SquareM\\
1657 \rrSl
1658 \end{minipage}%
1659 }
1660 \newcommand{\textRubikSl}{\rrSl\,\rrhM}

```

17.16.54 Rotation Slp

`\rrSlp` These commands draw forms of the Singmaster Slp slice rotation.

```

\rrhSlp 1661 \newcommand{\rrSlp}{\textbf{\textsf{S\footnotesize{1}}}$^\text{prime}$}
\RubikSlp 1662 \newcommand{\rrhSlp}{\rrhMp}%
\textRubikSlp 1663 \newcommand{\RubikSlp}{%
1664 \begin{minipage}{0.6cm}
1665 \centering
1666 \SquareMp\\
1667 \rrSlp
1668 \end{minipage}%
1669 }
1670 \newcommand{\textRubikSlp}{\rrSlp\,\rrhMp}

```

17.16.55 Rotation Sr

`\rrSr` These commands draw forms of the Singmaster Sr slice rotation.

```

\rrhSr 1671 \newcommand{\rrSr}{\textbf{\textsf{S\footnotesize{r}}}}
\RubikSr 1672 \newcommand{\rrhSr}{\rrhMp}%
\textRubikSr 1673 \newcommand{\RubikSr}{%
1674 \begin{minipage}{0.6cm}
1675 \centering
1676 \SquareMp\\
1677 \rrSr
1678 \end{minipage}%
1679 }

```

```
1680 \newcommand{\textRubikSr}{\rrSr\,\rrhMp}
```

17.16.56 Rotation Srp

```
\rrSrp These commands draw forms of the Singmaster Srp slice rotation.
\rrhSrp 1681 \newcommand{\rrSrp}{\textbf{\textsf{S\footnotesize{r}}}$^{\prime}$}}
\RubikSrp 1682 \newcommand{\rrhSrp}{\rrhM}%
\textRubikSrp 1683 \newcommand{\RubikSrp}{%
1684 \begin{minipage}{0.6cm}
1685 \centering
1686 \SquareM\
1687 \rrSrp
1688 \end{minipage}%
1689 }
1690 \newcommand{\textRubikSrp}{\rrSrp\,\rrhM}
```

17.16.57 Rotation Sf

```
\rrSf These commands draw forms of the Singmaster Sf slice rotation. We need to just
\rrhSf make square with Sf in square; adjust box height using a \rule; adjust \fboxsep
\RubikSf (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikSf reset to defaults. Not visible from the front.
1691 \newcommand{\rrSf}{\textbf{\textsf{S\footnotesize{f}}}}
1692 \newcommand{\SquareSf}{\@SquareLetter{\rrSf}}
1693 \newcommand{\rrhSf}{\raisebox{-0.25mm}{\SquareSf}\,,}
1694 \newcommand{\RubikSf}{\raisebox{\@hRubik}{\SquareSf}\,,}
1695 \newcommand{\textRubikSf}{\rrhSf\,,}
```

17.16.58 Rotation Sfp

```
\rrSfp These commands draw forms of the Singmaster Sfp slice rotation. We need to just
\rrhSfp make square with Sfp in square; adjust box height using a \rule; adjust \fboxsep
\RubikSfp (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikSfp reset to defaults. Not visible from the front.
1696 \newcommand{\rrSfp}{\textbf{\textsf{S\footnotesize{f}}}$^{\prime}$}}
1697 \newcommand{\SquareSfp}{\@SquareLetter{\rrSfp}}
1698 \newcommand{\rrhSfp}{\raisebox{-0.25mm}{\SquareSfp}\,,}
1699 \newcommand{\RubikSfp}{\raisebox{\@hRubik}{\SquareSfp}\,,}
1700 \newcommand{\textRubikSfp}{\rrhSfp\,,}
```

17.16.59 Rotation Sb

```
\rrSb These commands draw forms of the Singmaster Sb slice rotation. We need to just
\rrhSb make square with Sb in square; adjust box height using a \rule; adjust \fboxsep
\RubikSb (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikSb reset to defaults. Not visible from the front.
1701 \newcommand{\rrSb}{\textbf{\textsf{S\footnotesize{b}}}}
1702 \newcommand{\SquareSb}{\@SquareLetter{\rrSb}}
```



```

1703 \newcommand{\rrhSb}{\raisebox{-0.25mm}{\SquareSb}\,}
1704 \newcommand{\RubikSb}{\raisebox{\@hRubik}{\SquareSb}\,}
1705 \newcommand{\textRubikSb}{\rrhSb\,}

```

17.16.60 Rotation Sbp

`\rrSbp` These commands draw forms of the Singmaster Sbp slice rotation. We need to
`\rrhSbp` just make square with Sbp in square; adjust box height using a `\rule`; adjust
`\RubikSbp` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikSbp` need to reset to defaults. Not visible from the front.

```

1706 \newcommand{\rrSbp}{\textbf{\textsf{S}\footnotesize{b}}$\sim$prime$}
1707 \newcommand{\SquareSbp}{\@SquareLetter{\rrSbp}}
1708 \newcommand{\rrhSbp}{\raisebox{-0.25mm}{\SquareSbp}\,}
1709 \newcommand{\RubikSbp}{\raisebox{\@hRubik}{\SquareSbp}\,}
1710 \newcommand{\textRubikSbp}{\rrhSbp\,}

```

17.16.61 Rotation U

`\rrU` These commands all draw forms which denote the U rotation.

```

\SquareU 1711 \newcommand{\rrU}{\textbf{\textsf{U}}}
\rrhU    1712 %%
\RubikU  1713 \newcommand{\SquareU}{%
\textRubikU 1714 \begin{tikzpicture}[scale=0.5]
1715 \DrawNotationBox;
1716 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1717 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);
1718 \draw [thick]      (\@sb,\@sd) -- (\@sbh, \@sd);
1719 \end{tikzpicture}%
1720 }
1721 \newcommand{\rrhU}{\raisebox{-0.333\height}{\SquareU}\,}
1722 %%
1723 \newcommand{\RubikU}{%
1724 \begin{minipage}{0.6cm}
1725 \centering
1726 \SquareU\
1727 \rrU
1728 \end{minipage}%
1729 }
1730 \newcommand{\textRubikU}{\rrU\,\rrhU}

```

17.16.62 Rotation Uw

`\rrUw` These commands all draw forms which denote the Uw rotation.

```

\SquareUw 1731 \newcommand{\rrUw}{\textbf{\textsf{U}\footnotesize{w}}}
\rrhUw    1732 %%
\RubikUw  1733 \newcommand{\SquareUw}{%
\textRubikUw 1734 \begin{tikzpicture}[scale=0.5]
1735 \DrawNotationBox;
1736 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);

```

```

1737 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1738 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1739 \end{tikzpicture}%
1740 }
1741 %
1742 \newcommand{\rrhUw}{\raisebox{-0.333\height}{\SquareUw}\,,}
1743 %%
1744 \newcommand{\RubikUw}{%
1745 \begin{minipage}{0.6cm}
1746 \centering
1747 \SquareUw\
1748 \rrUw
1749 \end{minipage}}%
1750 }
1751 %%
1752 \newcommand{\textRubikUw}{\rrUw\,,\rrhUw}

```

17.16.63 Rotation Up

`\rrUp` These commands all draw forms which denote the Up rotation.

<code>\SquareUp</code>	1753 \newcommand{\rrUp}{\textbf{\textsf{U}}\$^\text{\prime}\$}
<code>\rrhUp</code>	1754 %%
<code>\RubikUp</code>	1755 \newcommand{\SquareUp}{%
<code>\textRubikUp</code>	1756 \begin{tikzpicture}[scale=0.5]
	1757 \DrawNotationBox;
	1758 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
	1759 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
	1760 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
	1761 \end{tikzpicture}%
	1762 }
	1763 \newcommand{\rrhUp}{\raisebox{-0.333\height}{\SquareUp}\,,}
	1764 %%
	1765 \newcommand{\RubikUp}{%
	1766 \begin{minipage}{0.6cm}
	1767 \centering
	1768 \SquareUp\
	1769 \rrUp
	1770 \end{minipage}}%
	1771 }
	1772 \newcommand{\textRubikUp}{\rrUp\,,\rrhUp}

17.16.64 Rotation Uwp

`\rrUwp` These commands all draw forms which denote the Uwp rotation.

<code>\SquareUwp</code>	1773 \newcommand{\rrUwp}{\textbf{\textsf{U}\footnotesize{w}}\$^\text{\prime}\$}}
<code>\rrhUwp</code>	1774 %%
<code>\RubikUwp</code>	1775 \newcommand{\SquareUwp}{%
<code>\textRubikUwp</code>	1776 \begin{tikzpicture}[scale=0.5]
	1777 \DrawNotationBox;

```

1778 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1779 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1780 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1781 \end{tikzpicture}%
1782 }
1783 \newcommand{\rrhUwp}{\raisebox{-0.333\height}{\SquareUwp}\,,}
1784 %%
1785 \newcommand{\RubikUwp}{%
1786 \begin{minipage}{0.6cm}
1787 \centering
1788 \SquareUwp\
1789 \rrUwp
1790 \end{minipage}}%
1791 }
1792 \newcommand{\textRubikUwp}{\rrUwp\,,\rrhUwp}

```

17.16.65 Rotation Us

\rrUs These commands all draw forms which denote the Us rotation.

```

\SquareUs 1793 \newcommand{\rrUs}{\@rrs{U}}
\rrhUs    1794 %%
\RubikUs  1795 \newcommand{\SquareUs}{%
\textRubikUs 1796 \begin{tikzpicture}[scale=0.5]
1797 \DrawNotationBox;
1798 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1799 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1800 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1801 \end{tikzpicture}%
1802 }
1803 \newcommand{\rrhUs}{\raisebox{-0.333\height}{\SquareUs}\,,}
1804 %%
1805 \newcommand{\RubikUs}{%
1806 \begin{minipage}{0.6cm}
1807 \centering
1808 \SquareUs\
1809 \rrUs
1810 \end{minipage}}%
1811 }
1812 \newcommand{\textRubikUs}{\rrUs\,,\rrhUs}

```

17.16.66 Rotation Usp

\rrUsp These commands all draw forms which denote the Usp rotation.

```

\SquareUsp 1813 \newcommand{\rrUsp}{\@rrsp{U}}
\rrhUsp    1814 %%
\RubikUsp  1815 \newcommand{\SquareUsp}{%
\textRubikUsp 1816 \begin{tikzpicture}[scale=0.5]
1817 \DrawNotationBox;
1818 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);

```

```

1819 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);
1820 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1821 \end{tikzpicture}%
1822 }
1823 \newcommand{\rrhUsp}{\raisebox{-0.333\height}{\SquareUsp}\,,}
1824 %%
1825 \newcommand{\RubikUsp}{%
1826 \begin{minipage}{0.6cm}
1827 \centering
1828 \SquareUsp\\
1829 \rrUsp
1830 \end{minipage}%
1831 }
1832 \newcommand{\textRubikUsp}{\rrUsp\,,\rrhUsp}

```

17.16.67 Rotation Ua

\rrUa These commands all draw forms which denote the Ua rotation.

```

\SquareUa 1833 \newcommand{\rrUa}{\@rra{U}}
\rrhUa    1834 %%
\RubikUa  1835 \newcommand{\SquareUa}{%
\textRubikUa 1836 \begin{tikzpicture}[scale=0.5]
1837 \DrawNotationBox;
1838 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1839 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);
1840 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1841 \end{tikzpicture}%
1842 }
1843 \newcommand{\rrhUa}{\raisebox{-0.333\height}{\SquareUa}\,,}
1844 %%
1845 \newcommand{\RubikUa}{%
1846 \begin{minipage}{0.6cm}
1847 \centering
1848 \SquareUa\\
1849 \rrUa
1850 \end{minipage}%
1851 }
1852 \newcommand{\textRubikUa}{\rrUa\,,\rrhUa}

```

17.16.68 Rotation Uap

\rrUap These commands all draw forms which denote the Uap rotation.

```

\SquareUap 1853 \newcommand{\rrUap}{\@rrap{U}}
\rrhUap    1854 %%
\RubikUap  1855 \newcommand{\SquareUap}{%
\textRubikUap 1856 \begin{tikzpicture}[scale=0.5]
1857 \DrawNotationBox;
1858 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1859 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);

```

```

1860 \draw [thick, <-]      (\@sb,\@sd) --      (\@sbh, \@sd);
1861 \end{tikzpicture}%
1862 }
1863 \newcommand{\rrhUap}{\raisebox{-0.333\height}{\SquareUap}\,,}
1864 %%
1865 \newcommand{\RubikUap}{%
1866 \begin{minipage}{0.6cm}
1867 \centering
1868 \SquareUap\\
1869 \rrUap
1870 \end{minipage}%
1871 }
1872 \newcommand{\textRubikUap}{\rrUap\,,\rrhUap}

```

17.16.69 Rotations x and xp

`\rrx` These commands all draw forms which denote the x rotation.

```

\rrhx 1873 \newcommand{\rrx}{\textbf{\textsf{x}}}
\Rubikx 1874 \newcommand{\Rubikx}{\@xyzRubik{x}}
1875 \newcommand{\rrhx}{\@xyzh{x}}

\rrxp These commands all draw forms which denote the xp rotation.
\rrhxp 1876 \newcommand{\rrxp}{\textbf{\textsf{x}}$\prime$}
\Rubikxp 1877 \newcommand{\Rubikxp}{\@xyzRubikp{x}}
1878 \newcommand{\rrhxp}{\@xyzhp{x}}

```

17.16.70 Rotations y and yp

`\rry` These commands all draw forms which denote the y rotation.

```

\rrhy 1879 \newcommand{\rry}{\textbf{\textsf{y}}}
\Rubiky 1880 \newcommand{\Rubiky}{\@xyzRubik{y}}
1881 \newcommand{\rrhy}{\@xyzh{y}}

\rryp These commands all draw forms which denote the yp rotation.
\rrhyp 1882 \newcommand{\rryp}{\textbf{\textsf{y}}$\prime$}
\Rubikyp 1883 \newcommand{\Rubikyp}{\@xyzRubikp{y}}
1884 \newcommand{\rrhyp}{\@xyzhp{y}}

```

17.16.71 Rotations z and zp

`\rrz` These commands all draw forms which denote the z rotation.

```

\rrhz 1885 \newcommand{\rrz}{\textbf{\textsf{z}}}
\Rubikz 1886 \newcommand{\Rubikz}{\@xyzRubik{z}}
1887 \newcommand{\rrhz}{\@xyzh{z}}

\rrzp These commands all draw forms which denote the zp rotation.
\rrhzp 1888 \newcommand{\rrzp}{\textbf{\textsf{z}}$\prime$}
\Rubikzp 1889 \newcommand{\Rubikzp}{\@xyzRubikp{z}}
1890 \newcommand{\rrhzp}{\@xyzhp{z}}

```

17.16.72 Rotations u and d

`\rru` These commands all draw forms which denote the u rotation.
`\rrhu` 1891 `\newcommand{\rru}{\textbf{\textsf{u}}}`
`\Rubiku` 1892 `\newcommand{\Rubiku}{\@xyzRubik{u}}`
1893 `\newcommand{\rrhu}{\@xyzh{u}}`

`\rrd` These commands all draw forms which denote the d rotation.
`\rrhd` 1894 `\newcommand{\rrd}{\textbf{\textsf{d}}}`
`\Rubikd` 1895 `\newcommand{\Rubikd}{\@xyzRubik{d}}`
1896 `\newcommand{\rrhd}{\@xyzh{d}}`

17.16.73 Rotations l and r

`\rrl` These commands all draw forms which denote the l rotation.
`\rrhl` 1897 `\newcommand{\rrl}{\textbf{\textsf{l}}}`
`\Rubikl` 1898 `\newcommand{\Rubikl}{\@xyzRubik{l}}`
1899 `\newcommand{\rrhl}{\@xyzh{l}}`

`\rrr` These commands all draw forms which denote the r rotation.
`\rrhr` 1900 `\newcommand{\rrr}{\textbf{\textsf{r}}}`
`\Rubikr` 1901 `\newcommand{\Rubikr}{\@xyzRubik{r}}`
1902 `\newcommand{\rrhr}{\@xyzh{r}}`

17.16.74 Rotations f and b

`\rrf` These commands all draw forms which denote the f rotation.
`\rrhf` 1903 `\newcommand{\rrf}{\textbf{\textsf{f}}}`
`\Rubikf` 1904 `\newcommand{\Rubikf}{\@xyzRubik{f}}`
1905 `\newcommand{\rrhf}{\@xyzh{f}}`

`\rrb` These commands all draw forms which denote the b rotation.
`\rrhb` 1906 `\newcommand{\rrb}{\textbf{\textsf{b}}}`
`\Rubikb` 1907 `\newcommand{\Rubikb}{\@xyzRubik{b}}`
1908 `\newcommand{\rrhb}{\@xyzh{b}}`

————— End of this package —————
1909 `</rubikcube>`

Index

Numbers written in *italic* refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in roman refer to the code lines where the entry is used.

Symbols	901, 902, 905,	912, 913, 917,
<code>\</code> , 19, 20, 900,	906, 907, 911,	918, 919, 923,

924,	925,	929,	1700,	1703,	971,	989,	990,
930,	931,	935,	1704,	1705,	991,	1009,	1010,
936,	937,	941,	1708,	1709,	1011,		1029,
942,	943,	954,	1710,	1721,	1030,		1031,
963,	974,	983,	1730,	1742,	1049,		1050,
994,	1003,	1014,	1752,	1763,	1051,		1069,
1023,		1034,	1772,	1783,	1070,		1071,
1043,		1054,	1792,	1803,	1089,		1090,
1063,		1074,	1812,	1823,	1091,		1109,
1083,		1094,	1832,	1843,	1110,		1111,
1103,		1114,	1852,	1863,	1129,		1130,
1123,		1134,	\@SquareLetter . <u>11</u> ,		1131,		1245,
1143,		1152,	899,	904,	910,		1246,
1161,		1170,	916,	922,	928,		1265,
1179,		1190,	934,	940,	1221,		1267,
1199,		1209,	1226,		1231,		1285,
1218,		1222,	1236,		1602,		1286,
1223,		1224,	1607,		1692,		1287,
1227,		1228,	1697,	1702,	1707		1305,
1229,		1232,	\@gobble 28				1306,
1233,		1234,	\@hRubik <u>11</u> ,				1307,
1237,		1238,	901,	906,	912,		1325,
1239,		1250,	918,	924,	930,		1326,
1259,		1270,	936,	942,	1223,		1327,
1279,		1290,	1228,		1233,		1345,
1299,		1310,	1238,		1604,		1346,
1319,		1330,	1609,		1694,		1347,
1339,		1350,	1699,	1704,	1709		1365,
1359,		1370,	\@ifpackageloaded . . 6				1366,
1379,		1390,	\@join <u>27</u> ,				1367,
1399,		1410,	894,	895,	896,		1385,
1419,		1430,	\@err <u>11</u> , 898, 1601				1386,
1439,		1451,	\@rra <u>11</u> ,				1387,
1460,		1471,	933,	1064,	1230,		1405,
1480,		1491,	1360,	1561,	1833		1406,
1500,		1511,	\@rrap <u>11</u> ,				1407,
1520,		1531,	939,	1084,	1235,		1425,
1540,		1551,	1380,	1581,	1853		1426,
1560,		1571,	\@rrp <u>11</u> , 903, 1606				1427,
1580,		1591,	\@rrs <u>11</u> ,				1446,
1600,		1603,	921,	1024,	1220,		1447,
1604,		1605,	1320,	1521,	1793		1448,
1608,		1609,	\@rrsp <u>11</u> ,				1466,
1610,		1620,	927,	1044,	1225,		1467,
1630,		1640,	1340,	1541,	1813		1468,
1650,		1660,	\@rrw <u>11</u> , 909				1486,
1670,		1680,	\@rrwp <u>11</u> , 915				1487,
1690,		1693,	\@sb 888,				1488,
1694,		1695,	889,	949,	950,		1506,
1698,		1699,	951,	969,	970,		1507,
							1508,
							1526,
							1527,
							1528,
							1546,
							1547,
							1548,
							1566,
							1567,
							1568,
							1586,
							1587,
							1588,
							1716,
							1717,
							1718,
							1736,
							1737,
							1738,
							1758,
							1759,
							1760,
							1778,
							1779,
							1780,
							1798,
							1799,
							1800,
							1818,
							1819,
							1820,
							1838,
							1839,
							1840,
							1858,
							1859,
							1860

\@sbh .	889, 949, 950,	1839, 1840,	1387, 1407,
	951, 969, 970,	1858, 1859, 1860	1427, 1448,
	971, 989, 990,	\@scx . 890, 892, 1149,	1468, 1488,
	991, 1009, 1010,	1167, 1185, 1205	1508, 1528,
	1011, 1029,	\@scy . 891, 893, 1149,	1548, 1568,
	1030, 1031,	1167, 1185, 1205	1588, 1716,
	1049, 1050,	\@sd . 884, 885, 886,	1736, 1758,
	1051, 1069,	891, 951, 971,	1778, 1798,
	1070, 1071,	991, 1011, 1031,	1818, 1838, 1858
	1089, 1090,	1051, 1071,	\@sh 887, 889
	1091, 1109,	1091, 1111,	\@sqcx . . 892, 1186, 1206
	1110, 1111,	1131, 1245,	\@sqcy . . 893, 1186, 1206
	1129, 1130,	1265, 1285,	\@xyzRubik 11,
	1131, 1245,	1305, 1325,	1874, 1880,
	1246, 1247,	1345, 1365,	1886, 1892,
	1265, 1266,	1385, 1405,	1895, 1898,
	1267, 1285,	1425, 1446,	1901, 1904, 1907
	1286, 1287,	1466, 1486,	\@xyzRubikp
	1305, 1306,	1506, 1526,	11, 1877, 1883, 1889
	1307, 1325,	1546, 1566,	\@xyzh 11, 1875, 1881,
	1326, 1327,	1586, 1718,	1887, 1893,
	1345, 1346,	1738, 1760,	1896, 1899,
	1347, 1365,	1780, 1800,	1902, 1905, 1908
	1366, 1367,	1820, 1840, 1860	\@xyzhp
	1385, 1386,	\@sdd 885,	11, 1878, 1884, 1890
	1387, 1405,	890, 950, 970,	\@ 959, 979,
	1406, 1407,	990, 1010, 1030,	999, 1019, 1039,
	1425, 1426,	1050, 1070,	1059, 1079,
	1427, 1446,	1090, 1110,	1099, 1119,
	1447, 1448,	1130, 1246,	1139, 1157,
	1466, 1467,	1266, 1286,	1175, 1195,
	1468, 1486,	1306, 1326,	1214, 1255,
	1487, 1488,	1346, 1366,	1275, 1295,
	1506, 1507,	1386, 1406,	1315, 1335,
	1508, 1526,	1426, 1447,	1355, 1375,
	1527, 1528,	1467, 1487,	1395, 1415,
	1546, 1547,	1507, 1527,	1435, 1456,
	1548, 1566,	1547, 1567,	1476, 1496,
	1567, 1568,	1587, 1717,	1516, 1536,
	1586, 1587,	1737, 1759,	1556, 1576,
	1588, 1716,	1779, 1799,	1596, 1616,
	1717, 1718,	1819, 1839, 1859	1626, 1636,
	1736, 1737,	\@sddd 886, 949, 969,	1646, 1656,
	1738, 1758,	989, 1009, 1029,	1666, 1676,
	1759, 1760,	1049, 1069,	1686, 1726,
	1778, 1779,	1089, 1109,	1747, 1768,
	1780, 1798,	1129, 1247,	1788, 1808,
	1799, 1800,	1267, 1287,	1828, 1848, 1868
	1818, 1819,	1307, 1327,	
	1820, 1838,	1347, 1367,	

$\backslash \square$	378	1806, 1816, 1394, 1414, 1826, 1836, 1434, 1455, 1846, 1856, 1866, 1475, 1495, 1515, 1535, 1555, 1575, 1595, 1615, 1625, 1635, 1645, 1655, 1665, 1675, 1685, 1725, 1746, 1767, 1787, 1807, 1827, 1847, 1867
B		
$\backslash B$	15	$\backslash bl$ 675, 682, 685, 686, 690, 693, 694, 698, 702, 706, 710
$\backslash b$	17	$\backslash Blb$ 81, 111, 608, 650, 672
$\backslash Ba$	16	$\backslash blh$ 682, 684, 690, 692, 698, 699, 706, 707
$\backslash begin$ 37, 39, 46, 48, 846, 848, 855, 857, 864, 866, 873, 875, 947, 957, 967, 977, 987, 997, 1007, 1017, 1027, 1037, 1047, 1057, 1067, 1077, 1087, 1097, 1107, 1117, 1127, 1137, 1147, 1155, 1165, 1173, 1183, 1193, 1203, 1212, 1243, 1253, 1263, 1273, 1283, 1293, 1303, 1313, 1323, 1333, 1343, 1353, 1363, 1373, 1383, 1393, 1403, 1413, 1423, 1433, 1443, 1454, 1464, 1474, 1484, 1494, 1504, 1514, 1524, 1534, 1544, 1554, 1564, 1574, 1584, 1594, 1614, 1624, 1634, 1644, 1654, 1664, 1674, 1684, 1714, 1724, 1734, 1745, 1756, 1766, 1776, 1786, 1796,		$\backslash Blm$. . . 80, 110, 598, 650 $\backslash Blt$ 79, 109, 588, 634, 650 $\backslash Bmb$. . . 81, 111, 611, 672 $\backslash Bmm$ 80, 110, 601 $\backslash Bmt$. . . 79, 109, 591, 634 $\backslash Bp$ 15 $\backslash Brb$ 81, 111, 614, 656, 672 $\backslash Brm$. . . 80, 110, 604, 656 $\backslash Brt$ 79, 109, 594, 634, 656 $\backslash Bs$ 16 $\backslash bs$ 676, 683, 691, 700, 708 $\backslash Bw$ 16 $\backslash bw$ 674, 683, 686, 694, 701, 702, 708, 709, 710 $\backslash bx$. . 585, 589, 590, 592, 593, 595, 596, 599, 600, 602, 603, 605, 606, 609, 610, 612, 613, 615, 616 $\backslash by$. . 586, 589, 590, 592, 593, 595, 596, 599, 600, 602, 603, 605, 606, 609, 610, 612, 613, 615, 616
C		
$\backslash centering$. . 38, 47, 847, 856, 865, 874, 958, 978, 998, 1018, 1038, 1058, 1078, 1098, 1118, 1138, 1156, 1174, 1194, 1213, 1254, 1274, 1294, 1314, 1334, 1354, 1374,		$\backslash cmd$ 553 $\backslash colorlet$. . . 33, 34, 35 $\backslash csname$ 28 $\backslash cube@dxdydz$. . 773, 775 $\backslash Cubiedx$ 23, 797, 799, 849, 858, 867, 876 $\backslash Cubiedy$ 23, 797, 800, 849, 858, 867, 876 $\backslash cx$ 797, 807, 810, 818, 821, 829, 832, 840, 843 $\backslash cy$ 798, 807, 810, 818, 821, 829, 832, 840, 843
D		
$\backslash D$	15	
$\backslash d$	17	
$\backslash Da$	16	
$\backslash ddx$. . 464, 468, 469, 471, 472, 474, 475, 478, 479, 481, 482, 484, 485, 488, 489, 491, 492, 494, 495		
$\backslash ddy$. . 465, 468, 469, 471, 472, 474, 475, 478, 479, 481, 482, 484, 485, 488, 489, 491, 492, 494, 495		
$\backslash def$ 2, 3, 54, 55, 56, 59, 60, 61, 64, 65, 66, 69, 70, 71, 74, 75, 76, 79, 80, 81, 84, 85, 86, 89,		

	90, 91, 94, 95,	374, 376, 383,	1267,	1285,
	96, 99, 100, 101,	385, 387, 390,	1286,	1287,
	104, 105, 106,	392, 394, 397,	1305,	1306,
	109, 110, 111,	399, 401, 407,	1307,	1325,
	136, 137, 140,	409, 411, 414,	1326,	1327,
	141, 144, 145,	416, 418, 421,	1345,	1346,
	148, 149, 152,	423, 425, 432,	1347,	1365,
	153, 156, 157,	435, 438, 442,	1366,	1367,
	160, 161, 164, 165	445, 448, 452,	1385,	1386,
\definecolor		455, 458, 467,	1387,	1405,
	 29, 30, 31, 32	470, 473, 477,	1406,	1407,
\Dlb	... 71, 106, 278,	480, 483, 487,	1425,	1426,
	325, 487, 658, 665	490, 493, 503,	1427,	1446,
\Dlm	 70, 105,	505, 507, 510,	1447,	1448,
	271, 318, 477, 658	512, 514, 517,	1466,	1467,
\Dlt	... 69, 104, 264,	519, 521, 530,	1468,	1486,
	311, 467, 644, 658	532, 534, 537,	1487,	1488,
\Dmb	 71, 106,	539, 541, 544,	1506,	1507,
	280, 327, 490, 665	546, 548, 556,	1508,	1526,
\Dmm	70, 105, 273, 320, 480	559, 562, 565,	1527,	1528,
\Dmt	 69, 104,	568, 571, 574,	1546,	1547,
	266, 313, 470, 644	577, 580, 588,	1548,	1566,
\Dp	 15	591, 594, 598,	1567,	1568,
\draw	 169,	601, 604, 608,	1586,	1587,
	171, 173, 176,	611, 614, 685,	1588,	1716,
	178, 180, 183,	693, 701, 709,	1717,	1718,
	185, 187, 194,	786, 791, 794,	1736,	1737,
	196, 198, 201,	803, 806, 809,	1738,	1758,
	203, 205, 208,	814, 817, 820,	1759,	1760,
	210, 212, 216,	825, 828, 831,	1778,	1779,
	218, 220, 223,	836, 839, 842,	1780,	1798,
	225, 227, 230,	882, 949, 950,	1799,	1800,
	232, 234, 242,	951, 969, 970,	1818,	1819,
	244, 246, 249,	971, 989, 990,	1820,	1838,
	251, 253, 256,	991, 1009, 1010,	1839,	1840,
	258, 260, 264,	1011, 1029,	1858,	1859, 1860
	266, 268, 271,	1030, 1031,	\DrawCubieLD	
	273, 275, 278,	1049, 1050,	 801, 823, 868	
	280, 282, 289,	1051, 1069,	\DrawCubieLU	
	291, 293, 296,	1070, 1071,	 801, 834, 877	
	298, 300, 303,	1089, 1090,	\DrawCubieRD	
	305, 307, 311,	1091, 1109,	 801, 812, 859	
	313, 315, 318,	1110, 1111,	\DrawCubieRU	
	320, 322, 325,	1129, 1130,	 801, 801, 850	
	327, 329, 336,	1131, 1149,	\DrawCubieXYyz	... 22
	338, 340, 343,	1167, 1185,	\DrawFlatBack	31, 428,
	345, 347, 350,	1186, 1205,	584, 624, 630, 661	
	352, 354, 358,	1206, 1245,	\DrawFlatBackSide	.
	360, 362, 365,	1246, 1247,	 31, 660	
	367, 369, 372,	1265, 1266,	\DrawFlatDown	31, 428,

463, 620, 628, 668	\DrawRubikCubeLU ..	\DrawRubikLayerSideRBy
\DrawFlatDownSide .	 332, 332	 731, 742
..... 31, 667	\DrawRubikCubeRD ..	\DrawRubikLayerSideRM
\DrawFlatFront . 31,	 238, 238	 720
428, 552, 622, 640	\DrawRubikCubeRU ..	\DrawRubikLayerSideRMx
\DrawFlatFrontSide .	 190, 190, 237	 719, 755, 762
..... 31, 639	\DrawRubikCubeXY .. 22	\DrawRubikLayerSideRTx
\DrawFlatLeft 31, 428,	\DrawRubikFlat	 718, 754, 760
498, 621, 629, 654	 31, 553, 618	\DrawRubikLayerSideRTy
\DrawFlatLeftSide .	\DrawRubikLayerFace	 726, 736
..... 31, 653	 27, 380, 380	\DrawRubikLayerSideT
\DrawFlatRight . 31,	\DrawRubikLayerFaceAll	 634,
428, 525, 623, 647	 380, 404	641, 648, 655,
\DrawFlatRightSide .	\DrawRubikLayerSideB	662, 669, 732, 733
..... 31, 646	 637,	\DrawRubikLayerSideX\$_1\$X\$_2\$X\$_3\$
\DrawFlatUp 31,	644, 651, 658,	 712
428, 428, 619, 633	665, 672, 732, 739	\DrawRubikLayerSideXYp
\DrawFlatUpSide ...	\DrawRubikLayerSideL	 27
..... 29, 31, 632	 635,	\Drb ... 71, 106, 282,
\DrawNCubeAll .. 33, 766	642, 649, 656,	329, 493, 651, 665
\DrawNotationBox 881,	663, 670, 732, 746	\Drm 70, 105,
948, 968, 988,	\DrawRubikLayerSideLBx	275, 322, 483, 651
1008, 1028,	 716, 749, 763	\Drt ... 69, 104, 268,
1048, 1068,	\DrawRubikLayerSideLBy	315, 473, 644, 651
1088, 1108,	 728, 740	\Ds 16
1128, 1148,	\DrawRubikLayerSideLM	\Dw 16
1166, 1184,	 715	\dx .. 683, 685, 686,
1204, 1244,	\DrawRubikLayerSideLMx	691, 693, 694,
1264, 1284,	 714, 748, 761	699, 701, 702,
1304, 1324,	\DrawRubikLayerSideLR	707, 709, 710,
1344, 1364,	 758	776, 787, 792, 795
1384, 1404,	\DrawRubikLayerSideLTx	\dy .. 684, 685, 686,
1424, 1444,	 713, 747, 759	692, 693, 694,
1465, 1485,	\DrawRubikLayerSideLTy	700, 701, 702,
1505, 1525,	 723, 734	708, 709, 710,
1545, 1565,	\DrawRubikLayerSideMB	779, 787, 792, 795
1585, 1715,	 730	\dz .. 782, 787, 792, 795
1735, 1757,	\DrawRubikLayerSideMBy	
1777, 1797,	 729, 741	E
1817, 1837, 1857	\DrawRubikLayerSideMT	\E 16
\DrawRubikCube	 725	\end .. 41, 42, 50, 51,
.... 237, 237, 627	\DrawRubikLayerSideMTy	851, 852, 860,
\DrawRubikCubeFlat .	 724, 735	861, 869, 870,
..... 32, 626	\DrawRubikLayerSideR	878, 879, 952,
\DrawRubikCubeFrontFace	 636,	961, 972, 981,
..... 167,	643, 650, 657,	992, 1001, 1012,
191, 239, 286, 333	664, 671, 732, 753	1021, 1032,
\DrawRubikCubeLD ..	\DrawRubikLayerSideRBx	1041, 1052,
..... 285, 285	 721, 756, 764	1061, 1072,
		1081, 1092,

1101,	1112,	\Flm	60, 90,	1551,	1571,
1121,	1132,		144, 149, 152,	1591,	1721,
1141,	1150,		157, 176, 565, 657	1742,	1763,
1159,	1168,	\Flt .	59, 89, 136, 141,	1783,	1803,
1177,	1188,		169, 556, 637, 657	1823,	1843, 1863
1197,	1207,	\Fmb	61, 91, 160,		
1216,	1248,		165, 185, 577, 669	L	
1257,	1268,	\Fmm .	60, 90, 144, 149,	\L	15
1277,	1288,		152, 157, 178, 568	\l	17
1297,	1308,	\Fmt	59, 89, 136,	\La	16
1317,	1328,		141, 171, 559, 637	\Llb	76, 101, 164, 303,
1337,	1348,	\footnotesize	13, 14,		350, 517, 664, 670
1357,	1368,		15, 16, 17, 18,	\Llm	75, 100, 148, 156,
1377,	1388,		984, 1004, 1180,		296, 343, 510, 664
1397,	1408,		1200,	\Llt .	74, 99, 140, 289,
1417,	1428,		1300,		336, 503, 635, 664
1437,	1449,		1501,	\Lmb . . .	76, 101, 164,
1458,	1469,		1621,		305, 352, 519, 670
1478,	1489,		1641,	\Lmm . . .	75, 100, 148,
1498,	1509,		1661,		156, 298, 345, 512
1518,	1529,		1681,	\Lmt	74, 99, 140,
1538,	1549,		1696,		291, 338, 505, 635
1558,	1569,		1706, 1731, 1773	\Lp	15
1578,	1589,	\foreach . .	770, 771, 772	\Lrb	76, 101, 164, 307,
1598,	1618,	\Fp	15		354, 521, 642, 670
1628,	1638,	\Frb .	61, 91, 160, 165,	\Lrm	75, 100, 148, 156,
1648,	1658,		187, 580, 649, 669		300, 347, 514, 642
1668,	1678,	\Frm	60, 90,	\Lrt .	74, 99, 140, 293,
1688,	1719,		144, 149, 152,		340, 507, 635, 642
1728,	1739,		157, 180, 571, 649	\Ls	16
1749,	1761,	\Frt .	59, 89, 136, 141,	\Lw	16
1770,	1781,		173, 562, 637, 649	\lx	499, 504, 506,
1790,	1801,	\Fs	16		508, 511, 513,
1810,	1821,	\Fw	16		515, 518, 520, 522
1830,	1841,			\ly	500
1850,	1861, 1870	H			
\endcsname	28	\height . . .	954, 974,	M	
\Ep	16		994, 1014, 1034,	\M	16
\expandafter	28		1054,	\Mp	16
			1094,		
			1134,	N	
F			1170,	\ncubes	767, 770, 771, 772
\F	15		1209,	\NeedsTeXFormat	4
\f	17		1270,	\newcommand . . .	9, 10,
\Fa	16		1310,		11, 12, 13, 14,
\fbox	24, 45		1350,		15, 16, 17, 18,
\fboxrule	23		1390,		19, 20, 21, 22,
\fboxsep	23		1430,		23, 27, 36, 44,
\Flb .	61, 91, 160, 165,		1471,		53, 58, 63, 68,
	183, 574, 657, 669		1511,		73, 78, 83, 88,

93, 98, 103, 108,	1026,	1034,	1362,	1370,
119, 127, 135,	1036,	1043,	1372,	1379,
139, 143, 147,	1044,	1046,	1380,	1382,
151, 155, 159,	1054,	1056,	1390,	1392,
163, 167, 190,	1063,	1064,	1399,	1400,
237, 238, 285,	1066,	1074,	1402,	1410,
332, 380, 404,	1076,	1083,	1412,	1419,
428, 463, 498,	1084,	1086,	1420,	1422,
525, 552, 584,	1094,	1096,	1430,	1432,
618, 626, 632,	1103,	1104,	1439,	1440,
639, 646, 653,	1106,	1114,	1442,	1451,
660, 667, 674,	1116,	1123,	1453,	1460,
675, 676, 680,	1124,	1126,	1461,	1463,
688, 696, 704,	1134,	1136,	1471,	1473,
713, 714, 715,	1143,	1144,	1480,	1481,
716, 718, 719,	1146,	1152,	1483,	1491,
720, 721, 723,	1154,	1161,	1493,	1500,
724, 725, 726,	1162,	1164,	1501,	1503,
728, 729, 730,	1170,	1172,	1511,	1513,
731, 733, 739,	1179,	1180,	1520,	1521,
746, 753, 758,	1182,	1190,	1523,	1531,
766, 775, 797,	1192,	1199,	1533,	1540,
798, 801, 812,	1200,	1202,	1541,	1543,
823, 834, 845,	1209,	1211,	1551,	1553,
854, 863, 872,	1218,	1220,	1560,	1561,
881, 894, 895,	1221,	1222,	1563,	1571,
896, 897, 898,	1223,	1224,	1573,	1580,
899, 900, 901,	1225,	1226,	1581,	1583,
902, 903, 904,	1227,	1228,	1591,	1593,
905, 906, 907,	1229,	1230,	1600,	1601,
908, 909, 910,	1231,	1232,	1602,	1603,
911, 912, 913,	1233,	1234,	1604,	1605,
914, 915, 916,	1235,	1236,	1606,	1607,
917, 918, 919,	1237,	1238,	1608,	1609,
920, 921, 922,	1239,	1240,	1610,	1611,
923, 924, 925,	1242,	1250,	1612,	1613,
926, 927, 928,	1252,	1259,	1620,	1621,
929, 930, 931,	1260,	1262,	1622,	1623,
932, 933, 934,	1270,	1272,	1630,	1631,
935, 936, 937,	1279,	1280,	1632,	1633,
938, 939, 940,	1282,	1290,	1640,	1641,
941, 942, 943,	1292,	1299,	1642,	1643,
944, 946, 954,	1300,	1302,	1650,	1651,
956, 963, 964,	1310,	1312,	1652,	1653,
966, 974, 976,	1319,	1320,	1660,	1661,
983, 984, 986,	1322,	1330,	1662,	1663,
994, 996, 1003,	1332,	1339,	1670,	1671,
1004, 1006,	1340,	1342,	1672,	1673,
1014, 1016,	1350,	1352,	1680,	1681,
1023, 1024,	1359,	1360,	1682,	1683,

1690,	1691,	P		1270,	1290,
1692,	1693,	\pgfmathsetmacro	429,	1310,	1330,
1694,	1695,		430, 464, 465,	1350,	1370,
1696,	1697,		499, 500, 526,	1390,	1410,
1698,	1699,		527, 585, 586,	1430,	1451,
1700,	1701,		674, 675, 676,	1471,	1491,
1702,	1703,		682, 683, 684,	1511,	1531,
1704,	1705,		690, 691, 692,	1551,	1571,
1706,	1707,		698, 699, 700,	1591,	1603,
1708,	1709,		706, 707, 708,	1604,	1608,
1710,	1711,		767, 776, 779,	1609,	1693,
1713,	1721,		782, 797, 798,	1694,	1698,
1723,	1730,		884, 885, 886,	1699,	1703,
1731,	1733,		887, 888, 889,	1704,	1708,
1742,	1744,		890, 891, 892, 893	1709,	1721,
1752,	1753,	\prime	 12,	1742,	1763,
1755,	1763,		14, 16, 18, 20,	1783,	1803,
1765,	1772,		22, 964, 1004,	1823,	1843, 1863
1773,	1775,		1124, 1162,	\RCfiledate	 3, 5
1783,	1785,		1200, 1260,	\RCfileversion	... 2, 5
1792,	1793,		1300, 1420,	\RequirePackage	 8
1795,	1803,		1461, 1501,	\Rlb	. 66, 96, 161, 230,
1805,	1812,		1621, 1641,		256, 544, 643, 671
1813,	1815,		1661, 1681,	\Rlm	. 65, 95, 145, 153,
1823,	1825,		1696, 1706,		223, 249, 537, 643
1832,	1833,		1753, 1773,	\Rlt	. 64, 94, 137, 216,
1835,	1843,		1876, 1882, 1888		242, 530, 636, 643
1845,	1852,	\ProvidesPackage	... 5	\Rmb	 66, 96, 161,
1853,	1855,				232, 258, 546, 671
1863,	1865,	R		\Rmm	 65, 95, 145,
1872,	1873,	\R	 15		153, 225, 251, 539
1874,	1875,	\r	 17	\Rmt	 64, 94, 137,
1876,	1877,	\Ra	 16		218, 244, 532, 636
1878,	1879,	\raisebox	21, 22, 24,	\Rp	 15
1880,	1881,		900, 901, 905,	\rr	 14, 894
1882,	1883,		906, 911, 912,	\Rrb	. 66, 96, 161, 234,
1884,	1885,		917, 918, 923,		260, 548, 663, 671
1886,	1887,		924, 929, 930,	\rrB	 898
1888,	1889,		935, 936, 941,	\rrb	 1906
1890,	1891,		942, 954, 974,	\rrBa	 932
1892,	1893,		994, 1014, 1034,	\rrBap	 938
1894,	1895,		1054, 1074,	\rrBp	 903
1896,	1897,		1094, 1114,	\rrBs	 920
1898,	1899,		1134, 1152,	\rrBsp	 926
1900,	1901,		1170, 1190,	\rrBw	 908
1902,	1903,		1209, 1222,	\rrBwp	 914
1904,	1905,		1223, 1227,	\rrD	 944
1906,	1907, 1908		1228, 1232,	\rrd	 1894
\newlength	 25		1233, 1237,	\rrDa	 1064
\node	 1187		1238, 1250,	\rrDap	 1084

\rrDp	964	\rrhLa	1360	\rrl	1897
\rrDs	1024	\rrhLap	1380	\rrLa	1360
\rrDsp	1044	\rrhLp	1260	\rrLap	1380
\rrDw	984	\rrhLs	1320	\rrLp	1260
\rrDwp	1004	\rrhLsp	1340	\rrLs	1320
\rrE	1104	\rrhLw	1280	\rrLsp	1340
\rrEp	1124	\rrhLwp	1300	\rrLw	1280
\rrF	1144	\rrhM	1400, 1652, 1660, 1682, 1690	\rrLwp	1300
\rrf	1903	\rrhMp	1420, 1662, 1670, 1672, 1680	\rrm	65, 95, 145, 153, 227, 253, 541, 663
\rrFa	1230	\rrhR	1440	\rrM	1400
\rrFap	1235	\rrhr	1900	\rrMp	1420
\rrFp	1162	\rrhRa	1561	\rrR	1440
\rrFs	1220	\rrhRap	1581	\rrr	1900
\rrFsp	1225	\rrhRp	1461	\rrRa	1561
\rrFw	1180	\rrhRs	1521	\rrRap	1581
\rrFwp	1200	\rrhRsp	1541	\rrRp	1461
\rrh	14, 894	\rrhRw	1481	\rrRs	1521
\rrhB	898	\rrhRwp	1501	\rrRsp	1541
\rrhb	1906	\rrhS	1601	\rrRw	1481
\rrhBa	932	\rrhSb	1701	\rrRwp	1501
\rrhBap	938	\rrhSbp	1706	\rrS	1601
\rrhBp	903	\rrhSd	1631	\rrSb	1701
\rrhBs	920	\rrhSdp	1641	\rrSbp	1706
\rrhBsp	926	\rrhSf	1691	\rrSd	1631
\rrhBw	908	\rrhSfp	1696	\rrSdp	1641
\rrhBwp	914	\rrhSl	1651	\rrSf	1691
\rrhD	944	\rrhSlp	1661	\rrSfp	1696
\rrhd	1894	\rrhSp	1606	\rrSl	1651
\rrhDa	1064	\rrhSr	1671	\rrSlp	1661
\rrhDap	1084	\rrhSrp	1681	\rrSp	1606
\rrhDp	964	\rrhSu	1611	\rrSr	1671
\rrhDs	1024	\rrhSup	1621	\rrSrp	1681
\rrhDsp	1044	\rrhU	1711	\rrSu	1611
\rrhDw	984	\rrhu	1891	\rrSup	1621
\rrhDwp	1004	\rrhUa	1833	\rrt	64, 94, 137, 220, 246, 534, 636, 663
\rrhE	1104, 1622, 1630, 1632, 1640	\rrhUap	1853	\rrU	1711
\rrhEp	1124, 1612, 1620, 1642, 1650	\rrhUp	1753	\rru	1891
\rrhF	1144	\rrhUs	1793, 1813	\rrUa	1833
\rrhf	1903	\rrhUsp	1823, 1832	\rrUap	1853
\rrhFa	1230	\rrhUw	1731	\rrUp	1753
\rrhFap	1235	\rrhUwp	1773	\rrUs	1793
\rrhFp	1162	\rrhx	1873	\rrUsp	1813
\rrhFs	1220	\rrhxp	1876	\rrUw	1731
\rrhFsp	1225	\rrhy	1879	\rrUwp	1773
\rrhFw	1180	\rrhyp	1882	\rrx	1873
\rrhFwp	1200	\rrhz	1885	\rrxp	1876
\rrhL	1240	\rrhzp	1888	\rry	1879
\rrhl	1897	\rrL	1240	\rryp	1882

$\backslash\text{side@barR}$	680 , 688 , 718 , 719 , 720 , 721	$\backslash\text{SquareR}$	1440	1661 , 1681 , 1696 , 1706 , 1731 , 1773 , 1876 , 1882 , 1888 , 1894 , 1900 , 1903 , 1906	1671 , 1691 , 1701 , 1711 , 1753 , 1873 , 1879 , 1885 , 1891 , 1897
$\backslash\text{side@barT}$	680 , 696 , 723 , 724 , 725 , 726	$\backslash\text{SquareRa}$	1561		
$\backslash\text{Sl}$	15	$\backslash\text{SquareRap}$	1581		
$\backslash\text{Slp}$	15	$\backslash\text{SquareRp}$	1461		
$\backslash\text{Sp}$	16	$\backslash\text{SquareRs}$	1521		
$\backslash\text{space}$	5	$\backslash\text{SquareRsp}$	1541		
$\backslash\text{SquareB}$	898	$\backslash\text{SquareRw}$	1481		
$\backslash\text{SquareBa}$	932	$\backslash\text{SquareRwp}$	1501		
$\backslash\text{SquareBap}$	938	$\backslash\text{SquareS}$	1601		
$\backslash\text{SquareBp}$	903	$\backslash\text{SquareSb}$			
$\backslash\text{SquareBs}$	920		1702 , 1703 , 1704		
$\backslash\text{SquareBsp}$	926	$\backslash\text{SquareSbp}$		$\backslash\text{textCubieLD}$	23 , 845 , 863
$\backslash\text{SquareBw}$	908		1707 , 1708 , 1709	$\backslash\text{textCubieLU}$	23 , 845 , 872
$\backslash\text{SquareBwp}$	914	$\backslash\text{SquareSf}$		$\backslash\text{textCubieRD}$	23 , 845 , 854
$\backslash\text{SquareD}$	944		1692 , 1693 , 1694	$\backslash\text{textCubieRU}$	23 , 845 , 845
$\backslash\text{SquareDa}$	1064	$\backslash\text{SquareSfp}$		$\backslash\text{textRubik}$	14 , 894
$\backslash\text{SquareDap}$	1084		1697 , 1698 , 1699	$\backslash\text{textRubikB}$	898
$\backslash\text{SquareDp}$	964	$\backslash\text{SquareSp}$	1606	$\backslash\text{textRubikBa}$	932
$\backslash\text{SquareDs}$	1024	$\backslash\text{SquareU}$	1711	$\backslash\text{textRubikBap}$	938
$\backslash\text{SquareDsp}$	1044	$\backslash\text{SquareUa}$	1833	$\backslash\text{textRubikBp}$	903
$\backslash\text{SquareDw}$	984	$\backslash\text{SquareUap}$	1853	$\backslash\text{textRubikBs}$	920
$\backslash\text{SquareDwp}$	1004	$\backslash\text{SquareUp}$	1753	$\backslash\text{textRubikBsp}$	926
$\backslash\text{SquareE}$	1104 , 1626 , 1636	$\backslash\text{SquareUs}$	1793	$\backslash\text{textRubikBw}$	908
$\backslash\text{SquareEp}$		$\backslash\text{SquareUsp}$	1813	$\backslash\text{textRubikBwp}$	914
	1124 , 1616 , 1646	$\backslash\text{SquareUw}$	1731	$\backslash\text{textRubikD}$	944
$\backslash\text{SquareF}$	1144	$\backslash\text{SquareUwp}$	1773	$\backslash\text{textRubikDa}$	1064
$\backslash\text{SquareFa}$		$\backslash\text{Sr}$	15	$\backslash\text{textRubikDap}$	1084
	1231 , 1232 , 1233	$\backslash\text{Srp}$	15	$\backslash\text{textRubikDp}$	964
$\backslash\text{SquareFap}$		$\backslash\text{string}$	28	$\backslash\text{textRubikDs}$	1024
	1236 , 1237 , 1238	$\backslash\text{Su}$	15	$\backslash\text{textRubikDsp}$	1044
$\backslash\text{SquareFp}$	1162	$\backslash\text{Sup}$	15	$\backslash\text{textRubikDw}$	984
$\backslash\text{SquareFs}$				$\backslash\text{textRubikDwp}$	1004
	1221 , 1222 , 1223			$\backslash\text{textRubikE}$	1104
$\backslash\text{SquareFsp}$				$\backslash\text{textRubikEp}$	1124
	1226 , 1227 , 1228			$\backslash\text{textRubikF}$	1144
$\backslash\text{SquareFw}$	1180			$\backslash\text{textRubikFa}$	1230
$\backslash\text{SquareFwp}$	1200			$\backslash\text{textRubikFap}$	1235
$\backslash\text{SquareL}$	1240			$\backslash\text{textRubikFp}$	1162
$\backslash\text{SquareLa}$	1360			$\backslash\text{textRubikFs}$	1220
$\backslash\text{SquareLap}$	1380			$\backslash\text{textRubikFsp}$	1225
$\backslash\text{SquareLp}$	1260			$\backslash\text{textRubikFw}$	1180
$\backslash\text{SquareLs}$	1320			$\backslash\text{textRubikFwp}$	1200
$\backslash\text{SquareLsp}$	1340			$\backslash\text{textRubikL}$	1240
$\backslash\text{SquareLw}$	1280			$\backslash\text{textRubikLa}$	1360
$\backslash\text{SquareLwp}$	1300			$\backslash\text{textRubikLap}$	1380
$\backslash\text{SquareM}$	1400 , 1656 , 1686			$\backslash\text{textRubikLp}$	1260
$\backslash\text{SquareMp}$				$\backslash\text{textRubikLs}$	1320
	1420 , 1666 , 1676			$\backslash\text{textRubikLsp}$	1340
				$\backslash\text{textRubikLw}$	1280
					1300

<code>\textRubikM</code>	1400	21, 22, 908, 914,	358, 432, 655, 662
<code>\textRubikMp</code>	1420	920, 926, 932,	<code>\Umb</code> 56, 86,
<code>\textRubikR</code>	1440	938, 944, 964,	210, 374, 455, 641
<code>\textRubikRa</code>	1561	984, 1004, 1104,	<code>\Umm</code> 55, 85, 203, 367, 445
<code>\textRubikRap</code>	1581	1124, 1144,	<code>\Umt</code> 54, 84,
<code>\textRubikRp</code>	1461	1162, 1180,	196, 360, 435, 662
<code>\textRubikRs</code>	1521	1200, 1240,	<code>\Up</code> 15
<code>\textRubikRsp</code>	1541	1260, 1280,	<code>\Urb</code> 56, 86, 212,
<code>\textRubikRw</code>	1481	1300, 1400,	376, 458, 641, 648
<code>\textRubikRwp</code>	1501	1420, 1440,	<code>\Urm</code> 55, 85,
<code>\textRubikS</code>	1601	1461, 1481,	205, 369, 448, 648
<code>\textRubikSb</code>	1701	1501, 1611,	<code>\Urt</code> 54, 84, 198,
<code>\textRubikSbp</code>	1706	1621, 1631,	362, 438, 648, 662
<code>\textRubikSd</code>	1631	1641, 1651,	<code>\Us</code> 16
<code>\textRubikSdp</code>	1641	1661, 1671,	<code>\Uw</code> 16
<code>\textRubikSf</code>	1691	1681, 1691,	<code>\ux</code> 429, 433, 434,
<code>\textRubikSfp</code>	1696	1696, 1701,	436, 437, 439,
<code>\textRubikSl</code>	1651	1706, 1711,	440, 443, 444,
<code>\textRubikSlp</code>	1661	1731, 1753,	446, 447, 449,
<code>\textRubikSp</code>	1606	1773, 1873,	450, 453, 454,
<code>\textRubikSr</code>	1671	1876, 1879,	456, 457, 459, 460
<code>\textRubikSrp</code>	1681	1882, 1885,	<code>\uy</code> 430, 433, 434,
<code>\textRubikSu</code>	1611	1888, 1891,	436, 437, 439,
<code>\textRubikSup</code>	1621	1894, 1897,	440, 443, 444,
<code>\textRubikU</code>	1711	1900, 1903, 1906	446, 447, 449,
<code>\textRubikUa</code>	1833	<code>\typeout</code> 7	450, 453, 454,
<code>\textRubikUap</code>	1853		456, 457, 459, 460
<code>\textRubikUp</code>	1753		
<code>\textRubikUs</code>	1793	U	X
<code>\textRubikUsp</code>	1813	<code>\U</code> 15	<code>\x</code> 17, 770, 773
<code>\textRubikUw</code>	1731	<code>\u</code> 17	
<code>\textRubikUwp</code>	1773	<code>\Ua</code> 16	Y
<code>\textsc</code> 9, 10		<code>\Ulb</code> 56, 86, 208,	<code>\y</code> 17, 771, 773
<code>\textsf</code> 11, 12,		372, 452, 641, 655	
13, 14, 15, 16,		<code>\Ulm</code> 55, 85,	Z
17, 18, 19, 20,		201, 365, 442, 655	<code>\z</code> 17, 772, 773
		<code>\Ult</code> 54, 84, 194,	