

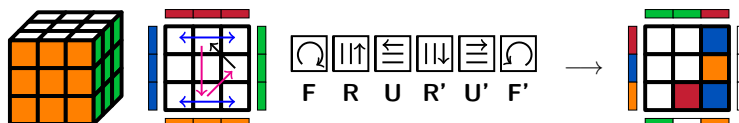
The RUBIKCUBE package

RWD Nickalls (dick@nickalls.org)
A Syropoulos (asyropoulos@yahoo.com)

This file describes version 5.0 (2018/02/25)
www.ctan.org/pkg/rubik

Abstract

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



Contents

1	Introduction	7
1.1	Requirements	7
1.2	rubikrotation package	8
1.3	rubikpatterns	8
1.4	rubiktwocube	8
1.5	Copyright	9
2	Installation	9
2.1	Generating the RUBIKCUBE files	9
2.2	RubikExamples file	10
2.3	Placing the files	10
2.4	Usage	10
3	Command conventions	11
3.1	Keywords Rubik and Two	11
3.2	Environments	12
3.3	Capital letters	12
3.4	XYZ argument ordering	12
3.5	Trailing % on the end of commands	13
3.6	Cubies, cubicles, faces and facelets	13

4 Rubik cube coordinates	14
4.1 Size of cube minipage	14
5 TikZ picture environment	15
6 ShowCube command	16
7 Optimum strategy	17
8 Colour commands	18
8.1 Colour state of the cube	19
8.2 RubikFace commands	20
8.3 RubikSolvedConfig command	21
8.4 RubikCubeSolved commands	21
8.5 RubikCubeGrey.. commands	23
8.6 RubikSlice commands	23
9 Rotation commands	24
9.1 Typesetting	25
9.2 Face rotations	25
9.3 Inner-slice rotations	26
9.4 Outer-slice rotations	27
9.5 Wide rotations	27
9.6 Axis rotations	28
9.7 Examples	29
9.8 Backwards compatibility	30
9.9 Listing of all rotation commands	30
9.9.1 Randelshofer notation	34
9.10 The rubikfont	36
10 Draw commands	37
10.1 Error message	38
10.2 DrawCubie commands	38
10.3 textCubie commands	39
10.4 DrawRubikCube commands	39
10.5 DrawRubikFace.. commands	41
10.6 Drawing Sidebars (Face)	41
10.7 Sidebar parameters	42
10.8 NoSidebar command	42
10.9 Drawing Sidebars (Cube)	43
10.10 DrawRubikFlat commands	44
10.11 DrawNCube	44
11 ShowSequence command	45
11.1 Trailing digits	46
12 SequenceBrace commands	47

13 Arrows	48
14 Final example	50
14.1 Without using <code>\RubikRotation</code>	51
15 Deprecated commands	51
16 Known limitations	51
17 Change history	52
18 Acknowledgements	54
19 References	54
20 The code (<code>rubikcube.sty</code>)	57
20.1 Package heading	57
20.2 Colours	58
20.3 The rubikfont	58
20.4 ShowCube command	58
20.5 ShowSequence command	59
20.6 SequenceBrace commands	61
20.7 RubikFace commands	61
20.8 RubikCubeGrey command	64
20.9 SolvedConfig command	64
20.10 RubikCubeGreyAll command	64
20.11 RubikCubeSolved command	65
20.12 Slice commands	65
20.13 Cube drawing macros	66
20.13.1 Viewing direction	67
20.14 DrawRubikFlatX commands	71
20.14.1 DrawRubikFaceXSide commands	76
20.15 DrawRubikFace commands	79
20.16 Sidebars (Face)	80
20.16.1 Drawing and allocating a colour to a single facelet sidebar	81
20.17 Sidebars (Cube)	83
20.17.1 Sidebars: RU view	83
20.17.2 Sidebars: LU view	85
20.17.3 Sidebars: RD view	87
20.17.4 Sidebars: LD view	89
20.18 DrawNCube command	90
20.19 Drawing single cubies	92
20.20 Text cubies	93
20.21 Rotation commands	94
20.21.1 Introduction	94
20.21.2 DrawNotationBox	95
20.21.3 Some useful internal commands	95

20.21.4	Using \@join	97
20.21.5	Rotation B	98
20.21.6	Rotation Bp	98
20.21.7	Rotation Bw	98
20.21.8	Rotation Bwp	98
20.21.9	Rotation Bs	99
20.21.10	Rotation Bsp	99
20.21.11	Rotation Ba	99
20.21.12	Rotation Bap	99
20.21.13	Rotation D	100
20.21.14	Rotation Dp	100
20.21.15	Rotation Dw	101
20.21.16	Rotation Dwp	101
20.21.17	Rotation Ds	102
20.21.18	Rotation Dsp	102
20.21.19	Rotation Da	103
20.21.20	Rotation Dap	103
20.21.21	Rotation E	104
20.21.22	Rotation Ep	104
20.21.23	Rotation F	105
20.21.24	Rotation Fp	105
20.21.25	Rotation Fw	106
20.21.26	Rotation Fwp	106
20.21.27	Rotation Fs	107
20.21.28	Rotation Fsp	107
20.21.29	Rotation Fa	107
20.21.30	Rotation Fap	107
20.21.31	Rotation L	108
20.21.32	Rotation Lp	108
20.21.33	Rotation Lw	109
20.21.34	Rotation Lwp	109
20.21.35	Rotation Ls	110
20.21.36	Rotation Lsp	110
20.21.37	Rotation La	111
20.21.38	Rotation Lap	111
20.21.39	Rotation M	112
20.21.40	Rotation Mp	112
20.21.41	Rotation R	113
20.21.42	Rotation Rp	113
20.21.43	Rotation Rw	114
20.21.44	Rotation Rwp	114
20.21.45	Rotation Rs	115
20.21.46	Rotation Rsp	115
20.21.47	Rotation Ra	116
20.21.48	Rotation Rap	116
20.21.49	Rotation S	117

20.21.50	Rotation Sp	117
20.21.51	Rotation Su	117
20.21.52	Rotation Sup	118
20.21.53	Rotation Sd	118
20.21.54	Rotation Sdp	118
20.21.55	Rotation Sl	119
20.21.56	Rotation Slp	119
20.21.57	Rotation Sr	119
20.21.58	Rotation Srp	119
20.21.59	Rotation Sf	120
20.21.60	Rotation Sfp	120
20.21.61	Rotation Sb	120
20.21.62	Rotation Sbp	121
20.21.63	Rotation U	121
20.21.64	Rotation Uw	121
20.21.65	Rotation Up	122
20.21.66	Rotation Uwp	122
20.21.67	Rotation Us	123
20.21.68	Rotation Usp	123
20.21.69	Rotation Ua	124
20.21.70	Rotation Uap	124
20.21.71	Rotations x and xp	125
20.21.72	Rotations y and yp	125
20.21.73	Rotations z and zp	125
20.21.74	Rotations u and d	126
20.21.75	Rotations l and r	126
20.21.76	Rotations f and b	126
20.22	Face(c) and Face(m) rotations	127
20.22.1	Rotations Rc and Rcp	127
20.22.2	Rotations Lc and Lcp	128
20.22.3	Rotations Uc and Ucp	128
20.22.4	Rotations Dc and Dcp	128
20.22.5	Rotations Fc and Fcp	128
20.22.6	Rotations Bc and Bcp	129
20.22.7	Rotations Rm and Rmp	129
20.22.8	Rotations Lm and Lmp	130
20.22.9	Rotations Um and Ump	130
20.22.10	Rotations Dm and Dmp	131
20.22.11	Rotations Fm and Fmp	131
20.22.12	Rotations Bm and Bmp	132
20.23	Randelshofer superset ENG rotations (CMST)	132
20.23.1	Rotations CR and CRp	133
20.23.2	Rotations CL and CLp	133
20.23.3	Rotations CU and CUp	134
20.23.4	Rotations CD and CDp	134
20.23.5	Rotations CF and CFp	134

20.23.6	Rotations CB and CBp	135
20.23.7	Rotations MR and MRp	135
20.23.8	Rotations ML and MLp	135
20.23.9	Rotations MU and MUp	136
20.23.10	Rotations MD and MDp	137
20.23.11	Rotations MF and MFp	137
20.23.12	Rotations MB and MBp	138
20.23.13	Rotations T (wide)	138
20.23.14	Rotations SR and SRp (opposite slices)	141
20.23.15	Rotations SL and SLp	141
20.23.16	Rotations SU and SUp	142
20.23.17	Rotations SD and SDp	142
20.23.18	Rotations SF and SFp	143
20.23.19	Rotations SB and SBp	144
20.24	Axis rotations (textRubik versions)	144

1 Introduction

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

The RUBIKCUBE package is the ‘base’ package of the bundle, and is required by all of the Rubik packages; it deals primarily with typesetting 3x3x3 cube (Rubik cube) configurations. The RUBIKROTATION package processes rotation sequences and keeps track of the cube’s configuration during rotations. The RUBIKPATTERNS package is a small database of 3x3x3 (Rubik) cube rotation sequences which generate well-known named cube configurations (patterns). The RUBIKTWOUCUBE package allows the typesetting of 2x2x2 cube (Two cube) configurations.

Full 3x3x3 functionality requires the following packages to be loaded (TikZ first; RUBIKCUBE second), as follows:

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

Full 2x2x2 functionality requires the RUBIKTWOUCUBE package *in addition* to the packages listed above. Note that the TikZ package must be loaded *before* the RUBIKCUBE package.

The RUBIKCUBE package has been road-tested on a Microsoft platform (with MiK_TEX), a GNU-Linux platform (Debian 8.2.0 and T_EXLive 2017), and on a Solaris platform (OpenIndiana).

For the mathematics and group theory associated with the Rubik cube see Chen (2004), Davis (2006), Fung website, Golomb (1981, 1982), Hofstadter (1981), Hutchings (2011), Heise website, Joyner (2008), Kociemba website, Rokicki *et al.* (2013), Scherphius website, Tran (2005). Other useful websites are the Speedsolving website, and those maintained by Duvoid, by Fridrich, by Jelinek, by Reid, and by Vandenburg. A useful online solver utility (based on an algorithm by Kociemba) is available at the RuWix website. Websites with good pages on patterns and symmetries are those by Fridrich, Kociemba, Longridge, Reid, Randelshofer, Scherphius (see References for details).

For historical and technical details regarding Rubik’s cube see Sher (2014), and also the Wikipedia article *Rubik’s Cube*.

1.1 Requirements

The RUBIKCUBE package requires the TikZ package, since it makes use of the TikZ picture environment and the `\pgfmathsetmacro` command. Consequently, the TikZ package must be loaded *before* the RUBIKCUBE package. The RUBIKROTATION package (see below) requires Perl to be installed.

1.2 Supporting tool—the rubikrotation package

The RUBIKROTATION package (also part of the RUBIK ‘bundle’), is a dynamic extension to the RUBIKCUBE package. It consists of the Perl program `rubikrotation.pl` and the associated style option `rubikrotation.sty`. The RUBIKROTATION package implements rotation sequences on-the-fly using a `\RubikRotation{<rotation-sequence>}` command. It returns the new state in a form which can then be used by the RUBIKCUBE package. It also returns some useful strings associated with the rotation sequence which can be used by the RUBIKCUBE package—see also Section 11.

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) the L^AT_EX engine needs to be run using the `--shell-escape` command-line option. Those wishing to use LuaL^AT_EX will also need to have access to the `shellesc` package (this can always be downloaded from CTAN directly). See the RUBIKROTATION documentation for further details. See also the examples in the file `RubikExamples.pdf`.

1.3 Supporting database—rubikpatterns package

The RUBIKPATTERNS.STY file (also part of the RUBIK ‘bundle’) is a small database of some well-known 3x3x3 cube (Rubik cube) rotation sequences, stored as named macros. For example, the ‘fourspot’ and ‘sixspot’ sequences are encoded in this package as follows:

```
\newcommand{\fourspot}{[fourspot],F2,B2,U,Dp,R2,L2,U,Dp,<(12q*, 8f*)>}
\newcommand{\sixspot}{[sixspot],U,Dp,R,Lp,F,Bp,U,Dp,<(8q*, 8f*)>}
```

These sequences can be processed by name (using the `\RubikRotation` command which also requires Perl to be installed—see Section 1.2), and then displayed (using the `\ShowCube` command in conjunction with various `\DrawRubikCube...` commands). So, for example, one could typeset the so-called ‘fourspot’ configuration using the following code:

```
\usepackage{tikz,rubikcube,rubikrotation,rubikpatterns}
...
\RubikCubeSolved
\RubikRotation{\fourspot} % this runs the Perl program \texttt{rubikrotation.pl}
\ShowCube{2.4cm}{0.6}{\DrawRubikCubeRU}
```

The sequence itself can be readily typeset using the `\ShowSequence` command (see Section 11). See also the RUBIKROTATION documentation—especially Section 5.1.1 *Sequences as macros*. See also the examples in the file `RubikExamples.pdf`.

1.4 Supporting 2x2x2 package—rubiktwocube package

The RUBIKTWOUCUBE package carries the macros and commands necessary for processing and displaying 2x2x2 cubes (TwoCubes). The 2x2x2 commands are isomorphic with the 3x3x3 commands—i.e., the word ‘Two’ has replaced the word

‘Rubik’ in commands. Consequently, users of this package will need to be familiar with the RUBIKCUBE package. There are lots of 2x2x2 examples in the file `RubikExamples.pdf`.

1.5 Copyright

Copyright 2014–2018 RWD Nickalls and A Syropoulos.

This work may be distributed and/or modified under the conditions of the LaTeX Project Public License, either version 1.3c of this license or any later version. The latest version of this licence is in www.latex-project.org/lppl.txt

2 Installation

The Rubik bundle consists of the four packages RUBIKCUBE, RUBIKROTATION, RUBIKPATTERNS and RUBIKTWOOCUBE. Although installing the Rubik bundle will typically install everything automatically (eg., from the T_EXLive DVD), each package can be installed separately if necessary. Here we detail only the RUBIKCUBE package.

2.1 Generating the rubikcube 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           --documentation of the rubikcube package
rubik-doc-figA.pdf
rubik-doc-figB.pdf
rubik-doc-figC.pdf
rubik-doc-figD.pdf
rubik-doc-figE.pdf
rubik-doc-figF.pdf
rubikexamples.tex
rubikexamples.pdf
rubikexamples.sh
rubikexamples.bat
```

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:

¹Several `pdflatex` runs are required, since the documentation includes an index as well as hyperref links (the package `hypdoc` is used). Prior to the first run it is a good idea to delete any relevant `.toc`, `.aux`, `.out` files.

```

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 RubikExamples file

Note that the package includes a ‘rubikexamples’ file (`rubikexamples.pdf`), as well as the source file (`rubikexamples.tex`), and associated `.sh` (Linux) and `.bat` (Microsoft) batch files, which can be used to facilitate processing the source `.tex` file. The file `rubikexamples.pdf` showcases both 3x3x3 (Rubik cube) and 2x2x2 (Two cube) examples.

Note that should you need to generate the file `rubikexamples.pdf` from the source file (`rubikexamples.tex`) you will require the RUBIKROTATION, RUBIKPATTERNS and RUBIKTWOUCUBE packages to be installed, and will also need to use the `--shell-escape` command-line option (see Section 1.2 for details).

2.3 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.

2.4 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:

```

\usepackage{tikz}
\usepackage{rubikcube,rubikrotation,rubikpatterns,rubiktwocube}

```

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, for full 3x3x3 functionality it is necessary to load the complementary packages RUBIKROTATION, RUBIKPATTERNS. For full 2x2x2 functionality you need to load all four packages.

3 Command conventions

All RUBIKCUBE package commands assume a 3x3x3 cube by default. Since all cubes are displayed or ‘drawn’ using the TikZ picture environment, it is useful (initially at least) to categorise commands with regard to this environment (and also with regard to the `\ShowCube...` command since this is simply a convenient wrapper for the TikZ picture environment). On this basis, we can distinguish three conceptually useful categories, as follows:

1. `\Draw...` commands (which must *always* be used *inside* a TikZ picture environment),
2. ‘parameter-allocation’ commands (which can be used either inside or outside a TikZ environment); for example, `\RubikFace...` (for allocating facelet colours), and
3. commands which can be used in ordinary text; for example, `\rr{}` (for typesetting certain rotation codes).

From a functional point of view, however, we can view the Rubik bundle commands as splitting into the following groups:

1. those that allocate colour to faces, facelets etc., —these commands all start with `\Rubik` (for 3x3x3 cubes) or `\Two` (for 2x2x2 cubes ²),
2. those that draw —these commands all start with `\Draw`,
3. those that typeset rotation codes or hieroglyphs; —there are just four of these for 3x3x3 cubes (these commands start with `\rr`, `\rrh`, `\Rubik`, and `\textRubik`), and an equivalent four commands for 2x2x2 cubes (these start with `\tr`, `\trh`, `\Two`, and `\textTwo`).

`\rubikcube` This command generates the logo RUBIKCUBE.

3.1 The keywords Rubik and Two in commands

In order to try and keep commands intuitive ³ we adopt the convention that the word ‘Rubik’ in a command reflects the fact that the command relates to a 3x3x3 cube (i.e., a ‘Rubik’ cube). Similarly, commands which relate to a 2x2x2 cube (a ‘Two’ cube) —see the RUBIKTWOOCUBE package— use instead the word ‘Two’. For example, the commands for drawing a 3x3x3 cube and a 2x2x2 cube from a RU viewpoint are respectively `\DrawRubikCubeRU` and `\DrawTwoCubeRU`.

Having packages now for both 3x3x3 and 2x2x2 cubes (v5) means we need to be more careful regarding command names, and try to make commands (a) as

²Requires the RUBIKTWOOCUBE package

³This is a tricky problem given the large number of commands, so any feedback or ideas on how to avoid ambiguity, including pruning or revising ‘bad’ commands, is always welcome.

intuitive as possible, and (b) use the same command name format for equivalent 3x3x3 and 2x2x2 commands (as shown in the example above).

In keeping with this approach, some commands have had to be renamed. For example, in this new version we have therefore renamed the earlier `\DrawFace..` commands \rightarrow `\DrawRubikFace..` (see Section 15).

3.2 Environments

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

Indeed, using RUBIKCUBE package 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 sequences of rotations across several figures; for example, keeping commands like `\RubikRotation`, `\RubikFace..`, `\RubikCubeSolved`, outside the environments keeps their effects global (an example of this problem is presented in the file `RubikExamples.pdf`).

3.3 Capital letters

Virtually all Rubik bundle commands start with a capital letter, primarily to avoid any confusion with TikZ commands (these generally start with lower-case letters). However, each ‘word’ in a Rubik bundle command (except the word ‘text’) also starts with a capital letter, primarily to facilitate readability. For example, `\DrawRubikCubeRU`, `\DrawCubieRU`. However, as with L^AT_EX, ‘text..’ commands start with a lower-case ‘t’; for example `\textCubieRU`. Letter arguments for colours (R, O, Y, G, B, W, X) are always written in upper-case letters.

3.4 XYZ argument ordering

Many commands have an appended two, three, or even six ordered arguments or letters which form some feature of the structure of a command; perhaps either face or colour code or a viewpoint direction.

We adopt the convention that where ordering of arguments is critical, then the arguments are ordered in the XYZ, +, − order. An XYZ code implies that the first letter in the code relates to an X-related parameter, for example, L (Left) or R (Right); the second letter 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) —see Figure 2.

Some commands have six arguments which adopt an (XYZ;+-) format. In this case, for example, the `\RubikSolvedConfig` command, for which the six colour arguments are ordered as X+, X-, Y+, Y-, Z+, Z-. Here the colour argument associated with a face positioned on the +ve axis is ordered before its -ve complement on the same axis.

Another example is the `\DrawCubieRU{G}{Y}{O}` command, which draws a cubie. Here the RU letters are XY ordered; i.e., 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.

3.5 Trailing % on the end of commands

Since the all the output of this package is drawn using graphic elements using TikZ, it is important to include a trailing % on the end of RUBIKCUBE package commands when used *outside* a TikZ picture environment, and also on the end of the `\end{tikzpicture}` environment command itself. In particular it is important 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 white-space. That this can occur is because in \TeX every newline character is automatically converted to a white space—unless you have an empty line (Feuersänger 2016).

The \LaTeX fbox is a useful aid for visualising unwanted white space which may have accumulated, and for identifying the cause. See Section 6 on the `\ShowCubeF` command for more details regarding this approach.

Although this effect is mostly small, and is generally only observed in situations when centering a graphic is critical, it is, however, cumulative and can be surprisingly large. In these situations, the cure is the addition of terminal % characters to preceding code guided by careful detective use of the fbox technique mentioned above.

3.6 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.

4 Rubik cube coordinates

The coordinate origin of all 2D cube images is located at the bottom-left corner of the FRONT face, as shown in Figure 1. Note also that the bottom left extent of this particular 2D rendering of the 3x3x3 cube is actually at $(-1, -1)$, and hence the default height and width of all oblique-view cubes is 4 units (i.e., equivalent to 4cm if the TikZ scale-factor = 1).

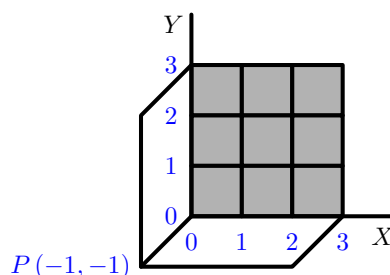


Figure 1: Origin of coordinates is at the bottom left corner of the grey FRONT face. Since P is at $(-1, -1)$ then the default height and width of the 2D cube image is 4 units.

Arranging for P to be at $(-1, -1)$, as well as using the bottom-left corner of the FRONT face as the origin, is a useful design feature which make it easy to figure-out the coordinates of any point on the image plane (either on the cube or outside the cube), and hence facilitates the use of TikZ commands (e.g., `\draw` and `\node` commands) to superimpose lines, arrows and text etc., onto the Rubik cube (see Section 13).

4.1 Size of cube \minipage

Since the the default height and width of the oblique 2D cube image is 4 units (see Section 4 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 $0.5 \times 4\text{cm} = 2\text{cm}$.

Note that the width of the semi-flat (SF) cube representation is therefore 10 units ($= 3+3+1+3$), and that of the flat (F) cube is 12 units ($= 3+3+3+3$) — see Section ?? for images of these forms. If in doubt check the horizontal extent of an image using the `\ShowCubeF` command, which places an fbox around the image.

5 TikZ picture environment

All the Rubik bundle `\Draw..` commands are designed to be used with the TikZ picture environment, and are compatible with standard TikZ. For a basic introduction to the use of TikZ see the following manuals (from CTAN or from <http://altermundus.com/>).

- <https://en.wikipedia.org/wiki/PGF/TikZ>
- `pgfmanual.pdf`, version 3.0.1a (2015) (1161 pages)
- `pgfplot.pdf`, version 1.14 (2016) (561 pages)
- `tkz-base-screen.pdf`, version 1.16c (2011) (91 pages)

An example of the TikZ picture environment for use with the Rubik bundle is as follows:

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

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

USEFUL COMMANDS: Probably the most useful TikZ commands for use with regard to the Rubik bundle are the `\draw` command (for drawing lines, arrows, circles), and the `\node` command (for writing text at specific coordinate locations). The basic structure of these commands is as follows, where (x,y) represent grid coordinates of start or end points of lines or arrows, or of a circle centre, or of text position (see Sections 10.4 and 13 for examples).

```
\draw[->,thick,color=blue] (4.5, 2.5) -- (3.5,2.5);
\draw[->,ultra thick,color=red] (4.5, 2.5) -- (3.5,2.5);
\draw [color=blue, thick] (0.3, 0.3) circle (1.3);
\node (B) at (7.5, 1.5) [black]{\small\textsf{B}};
```

Remember that all TikZ commands which are valid inside a `tikzpicture` environment require a terminal semicolon (see Section 13 for examples).

COLOURS: The following colors are predefined by TikZ: red, green, blue, cyan, magenta, yellow, black, gray, darkgray, lightgray, brown, lime, olive, orange, pink, purple, teal, violet and white (see <https://en.wikipedia.org/wiki/PGF/TikZ>).

LINE WIDTH: TikZ allows line width to be specified directly (e.g., [`line width=<dimension>`]), or by using the following abbreviations: ‘ultra thin’ for 0.1pt, ‘very thin’ for 0.2pt, ‘thin’ for 0.4pt (the default width), ‘semi thick’ for 0.6pt, ‘thick’ for 0.8pt, ‘very thick’ for 1.2pt, ‘ultra thick’ for 1.6pt (see <https://en.wikipedia.org/wiki/PGF/TikZ>).

WHITE SPACE: A particularly useful feature of TikZ is that it automatically minimises any horizontal white-space. However, it is good practice to place a % symbol after the `\end{tikzpicture}` command to avoid additional white space inadvertently being added by L^AT_EX (see Section 3.5).

When making images it can be helpful to place them inside a minipage (e.g., using the `\ShowCube` command / environment below). A convenient approach is to first adjust the value of the `tikzpicture` scale-factor (to obtain the appropriate size), and then adjust the minipage-width as necessary, using the `fbox` associated with the `\ShowCubeF` command (see Section 4.1 for a useful guide on this).

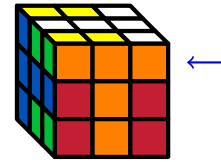
The main ‘display’ tool for drawing cubes is the `\ShowCube` command (see below), and this incorporates a TikZ picture environment inside a minipage. The equivalent tool for displaying rotation sequences is the `\ShowSequence` command.

6 \ShowCube command

\ShowCube This command `\ShowCube{<width>}{<scale-factor>}{<commands>}` is a convenient tool for placing one or more commands inside a `tikzpicture` environment which is also inside a minipage (see Section 20.4 for the code). This command takes three arguments: the first (#1) is the minipage width, the second (#2) is the `tikzpicture` scale factor, and the third (#3) is a series of any RUBIKCUBE package `\Draw..` and other commands, as well as any TikZ commands which are valid in a `tikzpicture` environment (e.g., `\draw` or `\node` etc.).

USAGE: The following `\ShowCube` command displays a Rubik cube (the ‘SixT’s configuration⁴) and a blue arrow in a minipage of width 3cm, using a `tikzpicture` scale factor of 0.5. Note that the TikZ `\draw` command requires a terminal semicolon (see Section 5).

```
\RubikCubeSolved
\RubikRotation{\sixts}
\ShowCube{3cm}{0.5}{%
  \DrawRubikCubeLU
  \draw[->,thick,color=blue] (4.5, 2.5) -- (3.5,2.5);
}
```



The action of the `\ShowCube` command is illustrated below; the `\ShowCube` command on the left is equivalent to the bunch of commands on the right (see Section 20.4 for the complete code).

$$\text{\ShowCube{3cm}{0.5}{...}} \left\{ \begin{array}{l} \text{\begin{minipage}{3cm}\%} \\ \text{\centering\%} \\ \text{\begin{tikzpicture}[scale=0.5]} \\ \text{...} \\ \text{\end{tikzpicture}\%} \\ \text{\end{minipage}\%} \end{array} \right.$$

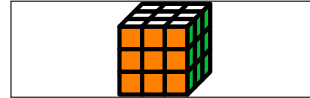
\ShowCubeF The `\ShowCubeF` command is similar in all respects except that it places an `fbox` around the minipage in order to enable users to see the extent of any associated white space. For example, unexpected spacing between two adjacent images, or between an image and adjacent text, is usually related to ‘hidden’ white-space associated with the image itself or excessive width of the associated `\minipage`

⁴The `\sixts` macro is from the RUBIKPATTERNS package.

(see also Section 3.5). 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 white-space). Use the `\ShowCubeF` command for this.

For example, the following use of the `\ShowCubeF` command reveals a significant white-space problem:

```
\ShowCubeF{4cm}{0.3}{\DrawRubikCubeRU}
```



In this example, 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 centres the image inside the minipage, \LaTeX positions the minipage in the `\textwidth`, and hence it is generally best to minimise the horizontal 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 4.1.

7 Optimum strategy

We suggest that the most convenient (and intuitive) approach for drawing cubes or particular faces is to do it in stages, as follows (all these steps are well illustrated in the examples file `RubikExamples.pdf`):

- first, start by setting the colour state of the cube. This can be done using either (a) a `\RubikCubeSolved..` or `\RubikCubeGrey..` command (for defining the whole cube), or (b) using one or more `\RubikFace..` commands (for defining parts of faces), or (c) by inputting a file containing a previously saved colour state⁵.
- second, use the `\RubikRotation` command to process a sequence of rotations (remembering that this requires use of the `--shell-escape` command-line option). The `RUBIKPATTERNS` package is a small library of named rotation sequences.
- third, draw the image(s) using `\DrawRubikCube..` or `\DrawRubikFace..` commands, plus any TikZ commands (e.g., `\draw` and/or `\node`) in conjunction with the `\ShowCube` command. Use the `\ShowCube` scale factor to adjust the size, and use the `\ShowCubeF` command to reveal the extent of any minipage whitespace.
- fourth, spacing between graphic elements can be influenced by adjusting either (a) horizontal whitespace as set by the `\ShowCube` command, or (b) using standard \TeX spacing commands, e.g., `\quad`, `\qquad`, `\hspace..` etc.

⁵See the `RUBIKROTATION` package documentation for details of the `\SaveRubikState` command; see also the ‘SaveRubikState’ example in the file `RubikExamples.pdf`.

- finally, give some thought to using a trailing % in commands which are broken across multiple lines (see Section 3.5).

With this approach the internal colour state will be updated and processed correctly by all subsequent `\Draw..` or `\RubikRotation` commands. Note that exchanging the word ‘Rubik’ for the word ‘Two’ in a command will generate the equivalent TwoCube version of the command (see Section 3.1).

8 Colour commands

The Rubik bundle of packages uses seven colours which are defined as follows: R (red), O (orange), Y (yellow), G (green), B (blue), W (white), and X (grey). Now according to the following webpage⁶

<http://The-Rubiks-Cube.deviantart.com/journal/Using-Official-Rubik-s-Cube-Colors-268760351> (Nov 2011)

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/)
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}
```

The following RGB specifications are given by Sher (2014):

```
White    {RGB}{255,255,255}
Red      {RGB}{137,18,20}
```

⁶We thank Peter Bartal for bringing this webpage to our attention.

```
Blue    {RGB}{13,72,172}
Orange  {RGB}{255,85,37}
Green   {RGB}{25,155,76}
Yellow  {RGB}{254,213,47}
```

However, we have tried to optimise 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 follows⁷ (see Section 20.2):

```
\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 standard L^AT_EX `\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.

8.1 Colour state of the cube

A given cubie facelet on a given face is denoted using an ordered sequence of three letters, as follows: first the face code (U,D,L,R,F,B), second the X-position of the column (l,m,r), and third the Y-position of the row (t,m,b). For example, the ‘right-bottom’ facelet of the FRONT face is denoted as **Frb**, and consequently the current colour-code (R,O,Y,G,B,W,X) of this facelet is held as the variable `\Frb` etc. (see Section 20.7 for details and code).

Initially, when L^AT_EX reads the file `rubikcube.sty` all facelets are allocated the colour-code X, which can be regarded as a zero-colour state. Until a facelet is allocated one of the six cube colours (using a suitable command) it will be rendered as grey by a `\Draw...` command, since these commands simply implement the current colour state of the cube (e.g., `\DrawRubikCubeRU`). Facelets retain their colour allocation even if they are moved using the `\RubikRotation` command (see RUBIKROTATION package), unless they are overwritten by a subsequent colour allocation command.

Colours are allocated to facelets using using `\Rubik..` commands. For example, the commands `\RubikCubeSolvedWY` and `\RubikCubeSolvedWB` allocate prescribed colour states for the whole ‘solved’ cube, and are a very useful starting

```
\RubikFace..
\RubikSlice..
\RubikCubeSolved..
\RubikCubeGrey..
\RubikCubeGreyAll
```

⁷Although the Pantone colours cannot be converted to RGB, there is a subset of of Pantone colours which can be converted using CMYK (see <https://en.wikipedia.org/wiki/Pantone>).

point (configuration) for subsequent rotations. The commands `\RubikCubeGreyWY` and `\RubikCubeGreyAll` allocate different colour states for the whole cube, and are designed to be useful starting points when illustrating aspects of how to solve the cube. These two commands accept both ‘grey’ and ‘gray’ (to be consistent with TikZ).

Colours can also be allocated to subsets of facelets (eg faces, slices etc); for example, using the commands `\RubikFace...` and `\RubikSlice...` commands (see Sections 8.2 and 8.6).

To visualise the current state of the cube one has to use a `\Draw...` command. `\Draw..` commands never influence the internal colour state of the cube.⁸

The current colour state / configuration of a cube can also be saved and written to a named file, which can then be `\input` and processed later when required, using the `\SaveRubikState` command (3x3x3 cube) or `\SaveTwoState` command (2x2x2 cube).

8.2 RubikFace commands

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

These commands allocate colours to the individual cubies of a 3x3x3 cube face; they take nine colour arguments (see Section 20.7 for the code). 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, L^AT_EX allows the colour arguments to be separated by spaces (e.g., in groups of three), or even spread across several lines (e.g., in a square block to resemble a 9-face). This is fortunate, as it allows the command to be written in several visually intuitive ways, as follows:

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

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

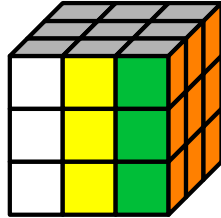
Failure to include a valid colour argument will generate a ‘missing parameter’ error, and no colour will be allocated (i.e., you will see a black-hole) when it is rendered.

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

Each of the above commands has an associated ‘All’ version which allocates the same colour to all the cubies on a 9-face (i.e., only a single colour argument is required). For example, if you want the RIGHT face to be all orange, then use

⁸That said, the now deprecated `\DrawRubikLayerFace...` and `\DrawRubikLayerSice...` commands (see Section 15) did, confusingly, allow you to specify colours as arguments, but they only ‘painted’ colours onto facelet positions (on the page, so to speak), and for this reason they are now deprecated, and will be phased out in due course.

the command `\RubikFaceRightAll{0}`. Use of these commands is shown in the following example.



```
\RubikCubeGreyAll
\RubikFaceRightAll{0}
\RubikFaceFront{W}{Y}{G}
    {W}{Y}{G}
    {W}{Y}{G}
\ShowCube{3cm}{0.7}{\DrawRubikCubeRU}
```

Note that instead of using `\RubikCubeGreyAll` we could have used the command `\RubikFaceUpAll{X}` to allocate grey to the whole of the UP face. However, the `\RubikCubeGreyAll` command can be a useful starting point when dealing with a new cube, since it resets all the faces to their initial default colour.

Finally, it is important to bear in mind that when allocating colours using the `\RubikFace..` commands it is very easy to inadvertently create a non-valid cube (ie a cube with either the wrong number of facelets with particular colours, or one which has a non-sovable configuration). However, some basic error checking of this sort is done whenever the `\RubikRotation` command is used (see the RUBIKROTATION package documentation).

8.3 RubikSolvedConfig command

`\RubikSolvedConfig` This command allocates the six face colours according to the following ordered XYZ+- argument rule, namely X+, X-, Y+, Y-, Z+, Z-; i.e., the order of the six colour arguments follows the face order RIGHT, LEFT, UP, DOWN, FRONT, BACK (for notation see Section 3.4 and Figure 2).
 USAGE: `\RubikSolvedConfig{G}{B}{W}{Y}{O}{R}`
 Examples of its use are shown in the next section.

8.4 RubikCubeSolved commands

`\RubikCubeSolved` `\RubikCubeSolvedWY` The action of both of these commands is identical: they both set all the face colours to the following standard ‘solved’ cube configuration, namely Up=white, Down=yellow, Right=green, Left=blue, Front=orange, Back=red, by invoking the above `\RubikSolvedConfig` command, as follows:

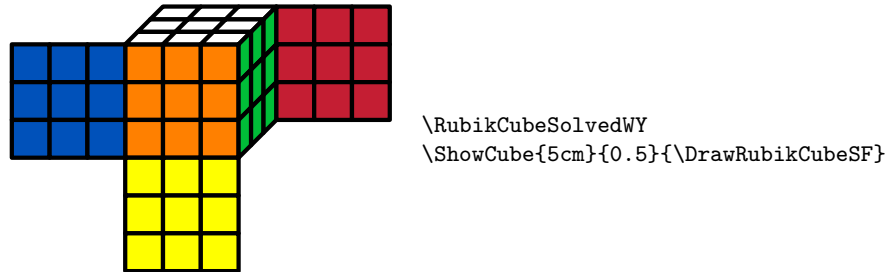
```
\newcommand{\RubikCubeSolved}{\RubikSolvedConfig{G}{B}{W}{Y}{O}{R}}
```

Note that this is in fact just a convenient short-hand for the following:

```
\newcommand{\RubikCubeSolved}{%
  \RubikFaceRightAll{G}%
  \RubikFaceLeftAll{B}%
  \RubikFaceUpAll{W}%
  \RubikFaceDownAll{Y}%
  \RubikFaceFrontAll{O}%
}
```

```
\RubikFaceBackAll{R}%
}
```

Note that for convenience, this configuration is also available using the command `\RubikCubeSolvedWY` (WY denoting White opposite Yellow). This solved configuration is shown in the following semi-flat (SF) image.

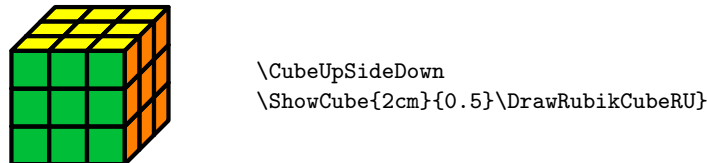


Note that the width of the minipage used in the `\ShowCube` command above is set to 5cm. This value is derived from the fact that the *unscaled* width of the semi-flat image is 10cm (9 + 1 squares), and hence if the TikZ scale factor is set to 0.5 (as in the above example) then the minimum minipage width = $10 \times 0.5 = 5\text{cm}$ (see Section 4 for details).

Other orientations: If other orientations of the solved cube are required, this can be easily achieved using the `\RubikRotation` command (from the `RubikRotation` package) to rotate the cube as required. For example, we could make a command to show the above solved cube upside-down and rotated slightly, as follows:

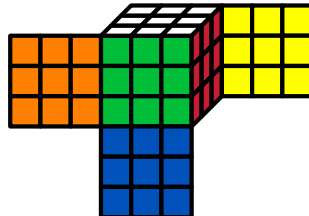
```
\newcommand{\CubeUpSideDown}{\RubikCubeSolved\RubikRotation{x2,y}}
```

—this uses the rotations **x**, **x**, to invert, and then **y** to turn the cube 90 deg:



`\RubikCubeSolvedWB`

Other configurations: While the ‘solved’ WY colour configuration described above (White face opposite Yellow) is that of the most commonly occurring Rubik cube, another ‘solved’ colour configuration which is also commercially available has the White opposite Blue configuration, which is available using the command `\RubikCubeSolvedWB`. Its colour configuration is as follows:

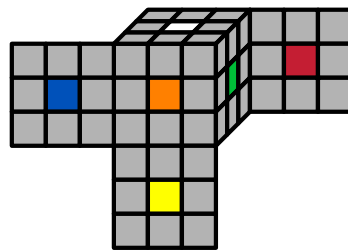


Note that users can easily create their own alternative ‘solved’ face/colour versions. For example, the above mentioned white opposite blue (WB) solved configuration command `\RubikCubeSolvedWB` (white opposite blue, red opposite orange, and green opposite yellow), was created using `\RubikSolvedConfig{R}{0}{W}{B}{G}{Y}` (for the code see 20.11).

8.5 RubikCubeGrey.. commands

`\RubikCubeGreyWY` The command `\RubikCubeGreyWY` 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 `\RubikCubeSolvedWY` command. The command `\RubikCubeGreyWB` generates a cube with *all* the faces completely grey; this is useful as it can be used to reset all the facelets to the initial default state. These commands will accept either ‘grey’ or ‘gray’ (to be consistent with TikZ).

These commands, are designed to be useful starting points when wanting to describe the movement of particular cubies. We can see the effect of the `\RubikCubeGreyWY` command by viewing the cube in a semi-flat (SF) format, as follows:



```
\RubikCubeGreyWY
\ShowCube{4.5cm}{0.45}{\DrawRubikCubeSF}
```

Users can of course set up their own alternative face/colour configuration by creating a new ‘variant’ command altogether.

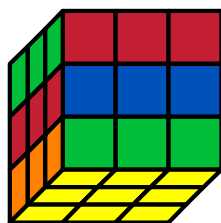
8.6 RubikSlice commands

`\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.

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}
```

9 Rotation commands

The Rubik bundle implements not only the standard Rubik cube notation of the World Cube Association (see WCA website), but also the main variant notations used by the Rubik interest groups and websites.

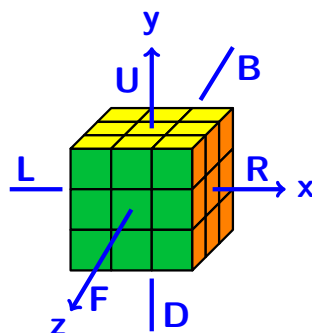


Figure 2: Face rotations

To avoid confusion the Rubik bundle uses a trailing ‘p’ (lower case) in rotation-codes to denote a ‘prime’ (reversed direction); we also recommend that commas are used to separate sequential Rubik rotations (moves). While these are mainly to avoid ambiguity, they also greatly facilitate computer searching and copy-and-pasting of rotation sequences.

Unfortunately, obtaining a good balance between an intuitive notation for defining rotations and the need for flexibility is difficult, and consequently some notation is more intuitive than others. A good compromise seems to be the World Cube Association’s FADN structure; i.e., Face (L,R,U,D,F,B), Action (m,w,s,a,c), Direction (p), N (n); for example, codes like **R**, **R2**, **Rc**, **Rm**, **Rwp**, **Rwp2** etc.

The RUBIKCUBE package includes commands for typesetting a wide range of rotation-codes (e.g., **R**, **y**, **Bw**) and equivalent hieroglyphs (e.g., $\boxed{\uparrow\uparrow}$, \boxed{y} , \boxed{Bw}), as well as commands for typesetting 3x3x3 cubes⁹ and single cubies. All the rotation-codes and hieroglyphs are typeset using one particular font & size which we call the ‘rubikfont’ for convenience (see Section 9.10 for details). All of the

⁹See the RUBIKTWOCUBE package documentation for 2x2x2 cube commands.

rotation-codes described here are recognised by the RUBIKROTATION package (see Section 1.2).

Note that there are some rotation codes which are not represented by arrow hieroglyphs, since 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, $\boxed{\mathbf{Bw}}$, $\boxed{\mathbf{Fm}}$.

9.1 Typesetting

We now describe the four commands used for typesetting the various rotation-codes.

<code>\rr</code>	The text version of a rotation-code is typeset using the rubik-rotation command <code>\rr{<rotation-code>}</code> , i.e., \mathbf{R} is typeset using the command <code>\rr{R}</code> . The
<code>\rrh</code>	hieroglyph of a rotation is generated (in text) by using instead the command <code>\rrh{<rotation-code>}</code> . For example, the command <code>\rrh{R}</code> generates $\boxed{\uparrow\uparrow}$ which is the hieroglyph associated with the rotation \mathbf{R} .
<code>\Rubik</code>	A vertically combined rotation-code and its hieroglyph is generated using the command <code>\Rubik{<rotation-code>}</code> . For example, $\boxed{\uparrow\uparrow}$ is generated by the command <code>\Rubik{R}</code> , 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 cube-axis rotations) the only difference between the <code>\rrh{}</code> and <code>\Rubik{}</code> form is that the <code>\Rubik{}</code> form is elevated to sit on the baseline just like the other <code>\Rubik{}</code> hieroglyphs. For example, <code>\rrh{yp}</code> generates $\boxed{\mathbf{y'}}$, while <code>\Rubik{yp}</code> generates $\boxed{\mathbf{y'}}$.
<code>\textRubik</code>	A horizontally combined rotation-code and its hieroglyph (in sequence as in text) is generated using the command <code>\textRubik{<rotation-code>}</code> . For example, $\mathbf{R} \boxed{\uparrow\uparrow}$ is typeset using the command <code>\textRubik{R}</code> . A list of all rotation-code commands and their associated hieroglyphs is given in Section 9.9.



9.2 Face rotations

U	The six main faces of the cube are denoted as FRONT (towards the observer),
D	BACK, LEFT, RIGHT, UP, DOWN. The upper-case initial letter of each face-name
L	(\mathbf{F} , \mathbf{B} , \mathbf{L} , \mathbf{R} , \mathbf{U} , \mathbf{D}) denotes a clockwise 90-degree rotation of the face as shown in
R	Figure 2. For example, \mathbf{D} is generated by the ‘rubik rotation’ command <code>\rr{D}</code> .
F	An appended prime ‘ \prime ’ indicates an anticlockwise rotation; e.g., $\mathbf{F'}$. This is some-
B	times written as \mathbf{F}^{-1} . The ‘prime’ notation is achieved by appending a lower-case
Up	‘p’ to the face rotation command. For example, $\mathbf{R'}$ is generated by <code>\rr{Rp}</code> . More
Dp	formally, $\mathbf{R'}$ is the ‘inverse’ of \mathbf{R} .
Lp	The superscript 2 , or sometimes just an ordinary 2, indicates that the rotation
Rp	is applied twice. For example, \mathbf{R}^2 or $\mathbf{R2}$ denote <i>two</i> successive 90 degree clockwise
Fp	rotations of the RIGHT face; \mathbf{R}^3 is equivalent to $\mathbf{R'}$ etc.
Bp	

9.3 Inner-slice rotations

The Rubik cube (3x3x3) has three orthogonal so-called ‘inner’ slices (middle layers, middle 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** (i.e., its rotation is isomorphic to **R**). The inner-slice rotations form a group (the Slice group), originally described by John Conway (Frey and Singmaster, 1982, p 105).

The ‘m’ notation

Um Here ‘m’ stands for the ‘middle’ slice, namely that parallel to the designated FACE;
 Dm its rotation mirrors that of the FACE. The **m** must be in lower case. Each of these
 Lm rotation-codes has a complementary ‘prime’ version, formed by appending a ‘p’;
 Rm for example, **Rm** (`\rr{Rm}`) is a middle layer rotation  between the RIGHT and
 Fm LEFT faces, and is in the same direction as **R**. The code **Rm**’ (`\rr{Rmp}`) refers to
 Bm the same middle slice, but rotated in the opposite direction .




This notation, which was probably invented by Singmaster, was originally used on the Cube Lovers usenet group (1981–1997). It is now much used on the Jaap Puzzles website (see Scherphius J) —see also Section 20.22.

The ‘M’ notation

MU This variant of the above ‘middle’ slice notation (e.g., **MR** \equiv **Rm**) is part of the
 MD ‘superset’ notation of Randelshofer. As before, the rotation direction follows that
 ML of the designated FACE. Each has a complementary ‘prime’ version formed by
 MR appending a ‘p’. The **M** must be in upper case.
 MF
 MB

The MES notation

M An alternative but very confusing inner-slice notation (e.g., **Ep** \equiv **Um**) which is
 E occasionally used is the so-called MES notation as used in the Waterman algorithm
 S (Treep and Waterman 1987), and the Roux method (Giles Roux).

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 an inverse (prime) version.

The ‘S’ notation

Su In this equally confusing inner-slice notation, ‘S’ stands for ‘inner-slice’; the face
Sd letter must be in lower case (e.g., $\mathbf{Sr} \equiv \mathbf{Rm}$). For example, the inner-slice rotation
Sl between the RIGHT and LEFT faces whose rotation direction follows the rotation
Sr \mathbf{R} is denoted as \mathbf{Sr} , which is typeset using the command `\rr{Sr}`. Each has an
Sf inverse (prime) p-form.
Sb

9.4 Outer-slice rotations

The ‘s’ (slice) notation

Us This is a ‘paired’ form of notation (two rotations at once), which can be thought
Ds of as complementing the inner-slice (middle layer) rotations. Each of these
Ls ‘slice’ commands denotes a rotation of two opposite faces in the *same* direction.
Rs For example, $\mathbf{Us} \begin{bmatrix} \leftarrow \\ \rightarrow \end{bmatrix} \equiv \mathbf{U} \begin{bmatrix} \leftarrow \\ \leftarrow \end{bmatrix} + \mathbf{D}' \begin{bmatrix} \rightarrow \\ \rightarrow \end{bmatrix}$; i.e., both face-rotations are in the *same*
Fs direction as \mathbf{U} . Each of these rotation-codes has a complementary ‘anti-slice’ ver-
Bs sion (see below).

This notation was originally described by Singmaster (Frey and Singmaster, 1982), and is much used on the ‘Pretty patterns’ page of the Fridrich website (this page also has a useful link to ‘notation’).

SU This variant of the above ‘slice’ notation (e.g., $\mathbf{SU} \equiv \mathbf{Us}$) is part of the ‘superset’
SD notation of Randelshofer. As before, the rotation direction follows that of the
SL designated FACE. Each has a complementary ‘prime’ version formed by appending
SR a ‘p’.
SF
SB

The ‘a’ (anti-slice) notation

Ua Each of these commands denotes a rotation of two opposite faces in *opposite*
Da directions. For example, $\mathbf{Ua} \begin{bmatrix} \leftarrow \\ \rightarrow \end{bmatrix} \equiv \mathbf{U} \begin{bmatrix} \leftarrow \\ \leftarrow \end{bmatrix} + \mathbf{D} \begin{bmatrix} \rightarrow \\ \rightarrow \end{bmatrix}$. This notation is much used
La on the ‘Pretty patterns’ page of the Fridrich website (see the note above re: ‘slice
Ra notation’).
Fa
Ba

9.5 Wide rotations

The ‘w’ notation

Uw The clockwise *combined* rotation of an outer face AND its adjacent inner-slice
Dw (officially known as a ‘double block’, or ‘double outer slice’ move) is denoted
Lw by appending a lower-case **w** (denoting ‘wide’) to a rotation-code (endorsed by
Rw the WCA). For example, a RIGHT double outer slice rotation $\begin{bmatrix} \uparrow \\ \uparrow \end{bmatrix}$ (`\rrh{Rw}`) is
Fw denoted as \mathbf{Rw} (`\rr{Rw}`). The ‘prime’ version is formed by appending a ‘p’ to
Bw the rotation-code. For example, \mathbf{Rw}' is generated by `\rr{Rwp}`.

The ‘T’ notation

TU This confusing variant of the above ‘w’ notation (e.g., $\text{TR} \equiv \text{Rw}$) is part of the
 TD ‘superset’ notation of Randelshofer. As before, the rotation direction follows that
 TL of the designated FACE. Each has a complementary ‘prime’ version formed by
 TR appending a ‘p’.
 TF
 TB

9.6 Axis rotations

The \mathbf{x} , \mathbf{y} , \mathbf{z} notation

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

For example, an $\mathbf{x2}$ rotation (two \mathbf{x} rotations one after the other, i.e., $[\mathbf{x}][\mathbf{x}]$)
 denotes rotating the cube 180 degrees about its \mathbf{x} axis so as to bring the DOWN
 face into the UP position.

An appended prime ‘ \prime ’ indicates an anticlockwise rotation; for example, \mathbf{x}' (which
 is generated by appending a ‘p’ to the rotation-code, i.e., $\backslash\mathbf{rr}\{\mathbf{x}\mathbf{p}\}$).

The $\backslash\mathbf{Rubik}\{\}$ forms (and their prime ‘p’ versions) generate the same hiero-
 glyphs as their $\backslash\mathbf{rrh}\{\}$ versions, except that their spacing is similar to that associ-
 ated with the ‘square box’ $\backslash\mathbf{Rubik}\{\}$ hieroglyphs. Consequently when typesetting
 an axis command in a sequence of ‘square-box’ $\backslash\mathbf{Rubik}\{\}$ commands, it is better to
 use the $\backslash\mathbf{Rubik}\{\}$ form rather than the equivalent $\backslash\mathbf{rrh}\{\}$ form (see the examples
 in Section 9.7). There are no $\backslash\mathbf{textRubik}\{\}$ forms for the axis commands (since
 they are not necessary).

The \mathbf{u} , \mathbf{d} , \mathbf{l} , \mathbf{r} , \mathbf{f} , \mathbf{b} notation

\mathbf{u} These are a commonly used alternative for the \mathbf{x} , \mathbf{y} , \mathbf{z} notation (and also endorsed
 \mathbf{d} by the WCA), and denote a 90 degree whole-cube rotation in the same directional
 \mathbf{l} sense as that of the associated face rotation.
 \mathbf{r} Thus $\mathbf{d} \equiv \mathbf{u}' \equiv \mathbf{y}'$ etc. For example, \mathbf{d} and \mathbf{d}' are generated by the commands
 \mathbf{f} $\backslash\mathbf{rr}\{\mathbf{d}\}$ and $\backslash\mathbf{rr}\{\mathbf{dp}\}$ respectively. Note that \mathbf{u} is the opposite of \mathbf{d} , \mathbf{l} is the opposite
 \mathbf{b} of \mathbf{r} , and \mathbf{f} is the opposite of \mathbf{b} , etc.

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

The ‘c’ notation

Uc This slightly more intuitive notation (the ‘c’ stands for ‘cube’) also associates
 Dc the rotation direction with that of the designated FACE (e.g., $\mathbf{Rc} \equiv \mathbf{x}$). Each has
 Lc a complementary ‘prime’ version formed by appending a ‘p’. For example, \mathbf{Rc}
 Rc ($\backslash\mathrm{rr}\{\mathbf{Rc}\}$) is equivalent to \mathbf{x} ; \mathbf{Rc}' ($\backslash\mathrm{rr}\{\mathbf{Rcp}\}$) is equivalent to \mathbf{x}' .

Fc This notation, which was probably invented by Singmaster, was originally used
 Bc on the Cube Lovers usenet group (1981–1997). It is now much used on the Jaap
 Puzzles website (see Scherphius J) —see also Section 20.22.

The ‘C’ notation

CU This variant of the whole cube rotation notation (e.g., $\mathbf{CR} \equiv \mathbf{Rc} \equiv \mathbf{x}$) is part of
 CD the ‘superset’ notation of Randelshofer. As before, the rotation direction follows
 CL that of the designated FACE. Each has a complementary ‘prime’ version formed
 CR by appending a ‘p’.

CF
 CB

9.7 Examples

\mathbf{R} is generated by the command $\backslash\mathrm{rr}\{\mathbf{R}\}$

\mathbf{Fw} is generated by the command $\backslash\mathrm{rr}\{\mathbf{Fw}\}$

\mathbf{L}^2 is generated by $\backslash\mathrm{rr}\{\mathbf{L}\}\$^2\$$

\mathbf{L}_2 is generated by $\backslash\mathrm{rr}\{\mathbf{L}\}_2$

\mathbf{R}' is generated by $\backslash\mathrm{rr}\{\mathbf{Rp}\}$

\mathbf{Fw}' is generated by $\backslash\mathrm{rr}\{\mathbf{Fwp}\}$

\mathbf{x} and $[\mathbf{y}]$ and $[\mathbf{z}']$ are generated by $\backslash\mathrm{rr}\{\mathbf{x}\}$ and $\backslash\mathrm{rrh}\{\mathbf{y}\}$ and $\backslash\mathrm{Rubik}\{\mathbf{zp}\}$

\mathbf{Fc} and $[\mathbf{Bc}]$ are generated by $\backslash\mathrm{rr}\{\mathbf{Fc}\}$ and $\backslash\mathrm{rrh}\{\mathbf{Bc}\}$

\mathbf{UURR} is generated by $\backslash\mathrm{rr}\{\mathbf{U}\}\backslash\mathrm{rr}\{\mathbf{U}\}\backslash\mathrm{rr}\{\mathbf{R}\}\backslash\mathrm{rr}\{\mathbf{R}\}$

$\backslash\mathrm{Rubik}\{\mathbf{F}\}\backslash\mathrm{Rubik}\{\mathbf{U}\}\backslash\mathrm{Rubik}\{\mathbf{y}\}\backslash\mathrm{Rubik}\{\mathbf{Rp}\}\backslash\mathrm{Rubik}\{\mathbf{Lwp}\}$
 $\mathbf{F} \quad \mathbf{U} \quad \mathbf{R}' \quad \mathbf{Lw}'$

$\mathbf{F} \backslash\mathrm{textRubik}\{\mathbf{F}\} \backslash\mathrm{textRubik}\{\mathbf{U}\}$

Commas can be important in avoiding ambiguity; for example,

$\mathbf{D}, \mathbf{U}_2, \mathbf{F}_2, \mathbf{Ds}_2, \mathbf{B},$ $\backslash\mathrm{rr}\{\mathbf{U}\}_2, \backslash\mathrm{rr}\{\mathbf{F}\}_2, \backslash\mathrm{rr}\{\mathbf{Ds}\}_2, \backslash\mathrm{rr}\{\mathbf{B}\},$

$\backslash\mathrm{rrh}\{\mathbf{U}\}_2, \backslash\mathrm{rrh}\{\mathbf{F}\}_2, \backslash\mathrm{rrh}\{\mathbf{Ds}\}_2$

Finally, if each rotation element uses the *same* font or encoding, for example

$\backslash\mathrm{rrh}\{\mathbf{F}\}\backslash\mathrm{rrh}\{\mathbf{U}\}\backslash\mathrm{rrh}\{\mathbf{y}\}\backslash\mathrm{rrh}\{\mathbf{Rp}\}\backslash\mathrm{rrh}\{\mathbf{Lwp}\}$

then typesetting such a rotation sequence can be achieved more easily using the $\backslash\mathrm{ShowSequence}$ command (see Section 11). For example, we can typeset the last sequence much more conveniently, as follows:

$\backslash\mathrm{ShowSequence}\{\}\{\backslash\mathrm{rrh}\}\{\mathbf{F}, \mathbf{U}, \mathbf{y}, \mathbf{Rp}, \mathbf{Lwp}\} \rightarrow \backslash\mathrm{Rubik}\{\mathbf{F}\}\backslash\mathrm{Rubik}\{\mathbf{U}\}\backslash\mathrm{Rubik}\{\mathbf{y}\}\backslash\mathrm{Rubik}\{\mathbf{Rp}\}\backslash\mathrm{Rubik}\{\mathbf{Lwp}\}$

9.8 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 $\boxed{\Rightarrow}$ (`\rrh{D}`) can also be generated using the command `\rrhD`.

9.9 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 (e.g., the `\rrh{B}` command) show only the lettercode in a square box, e.g., \boxed{B} . 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>	$\boxed{\Leftarrow}$ <code>\rrh{U}</code>	U $\boxed{\Leftarrow}$ <code>\textRubik{U}</code>
U' <code>\rr{Up}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Up}</code>	U' $\boxed{\Rightarrow}$ <code>\textRubik{Up}</code>
Uw <code>\rr{Uw}</code>	$\boxed{\Leftarrow}$ <code>\rrh{Uw}</code>	Uw $\boxed{\Leftarrow}$ <code>\textRubik{Uw}</code>
Uw' <code>\rr{Uwp}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Uwp}</code>	Uw' $\boxed{\Rightarrow}$ <code>\textRubik{Uwp}</code>
Us <code>\rr{Us}</code>	$\boxed{\Leftarrow}$ <code>\rrh{Us}</code>	Us $\boxed{\Leftarrow}$ <code>\textRubik{Us}</code>
Us' <code>\rr{Usp}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Usp}</code>	Us' $\boxed{\Rightarrow}$ <code>\textRubik{Usp}</code>
Ua <code>\rr{Ua}</code>	$\boxed{\Leftarrow}$ <code>\rrh{Ua}</code>	Ua $\boxed{\Leftarrow}$ <code>\textRubik{Ua}</code>
Ua' <code>\rr{Uap}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Uap}</code>	Ua' $\boxed{\Rightarrow}$ <code>\textRubik{Uap}</code>
Um <code>\rr{Um}</code>	$\boxed{\Leftarrow}$ <code>\rrh{Um}</code>	Um $\boxed{\Leftarrow}$ <code>\textRubik{Um}</code>
Um' <code>\rr{Ump}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Ump}</code>	Um' $\boxed{\Rightarrow}$ <code>\textRubik{Ump}</code>
Uc <code>\rr{Uc}</code>	\boxed{Uc} <code>\rrh{Uc}</code>	\boxed{Uc} <code>\Rubik{Uc}</code>
Uc' <code>\rr{Ucp}</code>	$\boxed{Uc'}$ <code>\rrh{Ucp}</code>	$\boxed{Uc'}$ <code>\Rubik{Ucp}</code>
D <code>\rr{D}</code>	$\boxed{\Rightarrow}$ <code>\rrh{D}</code>	D $\boxed{\Rightarrow}$ <code>\textRubik{D}</code>
D' <code>\rr{Dp}</code>	$\boxed{\Leftarrow}$ <code>\rrh{Dp}</code>	D' $\boxed{\Leftarrow}$ <code>\textRubik{Dp}</code>
Dw <code>\rr{Dw}</code>	$\boxed{\Rightarrow}$ <code>\rrh{Dw}</code>	Dw $\boxed{\Rightarrow}$ <code>\textRubik{Dw}</code>

Dw' \rr{Dwp}		Dw'  \textRubik{Dwp}
Ds \rr{Ds}		Ds  \textRubik{Ds}
Ds' \rr{Dsp}		Ds'  \textRubik{Dsp}
Da \rr{Da}		Da  \textRubik{Da}
Da' \rr{Dap}		Da'  \textRubik{Dap}
Dm \rr{Dm}		Dm  \textRubik{Dm}
Dm' \rr{Dmp}		Dm'  \textRubik{Dmp}
Dc \rr{Dc}		[Dc] \Rubik{Dc}
Dc' \rr{Dcp}		[Dc'] \Rubik{Dcp}
L \rr{L}		L  \textRubik{L}
L' \rr{Lp}		L'  \textRubik{Lp}
Lw \rr{Lw}		Lw  \textRubik{Lw}
Lw' \rr{Lwp}		Lw'  \textRubik{Lwp}
Ls \rr{Ls}		Ls  \textRubik{Ls}
Ls' \rr{Lsp}		Ls'  \textRubik{Lsp}
La \rr{La}		La  \textRubik{La}
La' \rr{Lap}		La'  \textRubik{Lap}
Lm \rr{Lm}		Lm  \textRubik{Lm}
Lm' \rr{Lmp}		Lm'  \textRubik{Lmp}
Lc \rr{Lc}		[Lc] \Rubik{Lc}
Lc' \rr{Lcp}		[Lc'] \Rubik{Lcp}
R \rr{R}		R  \textRubik{R}
R' \rr{Rp}		R'  \textRubik{Rp}
Rw \rr{Rw}		Rw  \textRubik{Rw}

$\mathbf{Rw}' \rr{Rwp}$	$\boxed{\Downarrow} \rrh{Rwp}$	$\mathbf{Rw}' \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Rwp\}}$
$\mathbf{Rs} \rr{Rs}$	$\boxed{\Uparrow} \rrh{Rs}$	$\mathbf{Rs} \boxed{\Uparrow} \text{\texttt{\textbackslash textRubik}\{Rs\}}$
$\mathbf{Rs}' \rr{Rsp}$	$\boxed{\Downarrow} \rrh{Rsp}$	$\mathbf{Rs}' \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Rsp\}}$
$\mathbf{Ra} \rr{Ra}$	$\boxed{\Downarrow} \rrh{Ra}$	$\mathbf{Ra} \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Ra\}}$
$\mathbf{Ra}' \rr{Rap}$	$\boxed{\Uparrow} \rrh{Rap}$	$\mathbf{Ra}' \boxed{\Uparrow} \text{\texttt{\textbackslash textRubik}\{Rap\}}$
$\mathbf{Rm} \rr{Rm}$	$\boxed{\Uparrow} \rrh{Rm}$	$\mathbf{Rm} \boxed{\Uparrow} \text{\texttt{\textbackslash textRubik}\{Rm\}}$
$\mathbf{Rm}' \rr{Rmp}$	$\boxed{\Downarrow} \rrh{Rmp}$	$\mathbf{Rm}' \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Rmp\}}$
$\mathbf{Rc} \rr{Rc}$	$\boxed{\mathbf{Rc}} \rrh{Rc}$	$\boxed{\mathbf{Rc}} \text{\texttt{\textbackslash Rubik}\{Rc\}}$
$\mathbf{Rc}' \rr{Rcp}$	$\boxed{\mathbf{Rc}'} \rrh{Rcp}$	$\boxed{\mathbf{Rc}'} \text{\texttt{\textbackslash Rubik}\{Rcp\}}$
$\mathbf{F} \rr{F}$	$\boxed{\curvearrowright} \rrh{F}$	$\mathbf{F} \boxed{\curvearrowright} \text{\texttt{\textbackslash textRubik}\{F\}}$
$\mathbf{F}' \rr{Fp}$	$\boxed{\curvearrowleft} \rrh{Fp}$	$\mathbf{F}' \boxed{\curvearrowleft} \text{\texttt{\textbackslash textRubik}\{Fp\}}$
$\mathbf{Fw} \rr{Fw}$	$\boxed{\odot} \rrh{Fw}$	$\mathbf{Fw} \boxed{\odot} \text{\texttt{\textbackslash textRubik}\{Fw\}}$
$\mathbf{Fw}' \rr{Fwp}$	$\boxed{\ominus} \rrh{Fwp}$	$\mathbf{Fw}' \boxed{\ominus} \text{\texttt{\textbackslash textRubik}\{Fwp\}}$
$\mathbf{Fs} \rr{Fs}$	$\boxed{\mathbf{Fs}} \rrh{Fs}$	$\boxed{\mathbf{Fs}} \text{\texttt{\textbackslash textRubik}\{Fs\}}$
$\mathbf{Fs}' \rr{Fsp}$	$\boxed{\mathbf{Fs}'} \rrh{Fsp}$	$\boxed{\mathbf{Fs}'} \text{\texttt{\textbackslash textRubik}\{Fsp\}}$
$\mathbf{Fa} \rr{Fa}$	$\boxed{\mathbf{Fa}} \rrh{Fa}$	$\boxed{\mathbf{Fa}} \text{\texttt{\textbackslash textRubik}\{Fa\}}$
$\mathbf{Fa}' \rr{Fap}$	$\boxed{\mathbf{Fa}'} \rrh{Fap}$	$\boxed{\mathbf{Fa}'} \text{\texttt{\textbackslash textRubik}\{Fap\}}$
$\mathbf{Fm} \rr{Fm}$	$\boxed{\mathbf{Fm}} \rrh{Fm}$	$\boxed{\mathbf{Fm}} \text{\texttt{\textbackslash textRubik}\{Fm\}}$
$\mathbf{Fm}' \rr{Fmp}$	$\boxed{\mathbf{Fm}'} \rrh{Fmp}$	$\boxed{\mathbf{Fm}'} \text{\texttt{\textbackslash textRubik}\{Fmp\}}$
$\mathbf{Fc} \rr{Fc}$	$\boxed{\mathbf{Fc}} \rrh{Fc}$	$\boxed{\mathbf{Fc}} \text{\texttt{\textbackslash Rubik}\{Fc\}}$
$\mathbf{Fc}' \rr{Fcp}$	$\boxed{\mathbf{Fc}'} \rrh{Fcp}$	$\boxed{\mathbf{Fc}'} \text{\texttt{\textbackslash Rubik}\{Fcp\}}$
$\mathbf{B} \rr{B}$	$\boxed{\mathbf{B}} \rrh{B}$	$\boxed{\mathbf{B}} \text{\texttt{\textbackslash textRubik}\{B\}}$
$\mathbf{B}' \rr{Bp}$	$\boxed{\mathbf{B}'} \rrh{Bp}$	$\boxed{\mathbf{B}'} \text{\texttt{\textbackslash textRubik}\{Bp\}}$
$\mathbf{Bw} \rr{Bw}$	$\boxed{\mathbf{Bw}} \rrh{Bw}$	$\boxed{\mathbf{Bw}} \text{\texttt{\textbackslash textRubik}\{Bw\}}$











































$\mathbf{Bw}' \rr{Bwp}$	$\boxed{\mathbf{Bw}'} \rrh{Bwp}$	$\boxed{\mathbf{Bw}'} \text{\texttt{\textbackslash textRubik}\{Bwp\}}$
$\mathbf{Bs} \rr{Bs}$	$\boxed{\mathbf{Bs}} \rrh{Bs}$	$\boxed{\mathbf{Bs}} \text{\texttt{\textbackslash textRubik}\{Bs\}}$
$\mathbf{Bs}' \rr{Bsp}$	$\boxed{\mathbf{Bs}'} \rrh{Bsp}$	$\boxed{\mathbf{Bs}'} \text{\texttt{\textbackslash textRubik}\{Bsp\}}$
$\mathbf{Ba} \rr{Ba}$	$\boxed{\mathbf{Ba}} \rrh{Ba}$	$\boxed{\mathbf{Ba}} \text{\texttt{\textbackslash textRubik}\{Ba\}}$
$\mathbf{Ba}' \rr{Bap}$	$\boxed{\mathbf{Ba}'} \rrh{Bap}$	$\boxed{\mathbf{Ba}'} \text{\texttt{\textbackslash textRubik}\{Bap\}}$
$\mathbf{Bm} \rr{Bm}$	$\boxed{\mathbf{Bm}} \rrh{Bm}$	$\boxed{\mathbf{Bm}} \text{\texttt{\textbackslash textRubik}\{Bm\}}$
$\mathbf{Bm}' \rr{Bmp}$	$\boxed{\mathbf{Bm}'} \rrh{Bmp}$	$\boxed{\mathbf{Bm}'} \text{\texttt{\textbackslash textRubik}\{Bmp\}}$
$\mathbf{Bc} \rr{Bc}$	$\boxed{\mathbf{Bc}} \rrh{Bc}$	$\boxed{\mathbf{Bc}} \text{\texttt{\textbackslash Rubik}\{Bc\}}$
$\mathbf{Bc}' \rr{Bcp}$	$\boxed{\mathbf{Bc}'} \rrh{Bcp}$	$\boxed{\mathbf{Bc}'} \text{\texttt{\textbackslash Rubik}\{Bcp\}}$
$\mathbf{Su} \rr{Su}$	$\boxed{\Leftarrow} \rrh{Su}$	$\mathbf{Su} \boxed{\Leftarrow} \text{\texttt{\textbackslash textRubik}\{Su\}}$
$\mathbf{Su}' \rr{Sup}$	$\boxed{\Rightarrow} \rrh{Sup}$	$\mathbf{Su}' \boxed{\Rightarrow} \text{\texttt{\textbackslash textRubik}\{Sup\}}$
$\mathbf{Sd} \rr{Sd}$	$\boxed{\Rightarrow} \rrh{Sd}$	$\mathbf{Sd} \boxed{\Rightarrow} \text{\texttt{\textbackslash textRubik}\{Sd\}}$
$\mathbf{Sd}' \rr{Sdp}$	$\boxed{\Leftarrow} \rrh{Sdp}$	$\mathbf{Sd}' \boxed{\Leftarrow} \text{\texttt{\textbackslash textRubik}\{Sdp\}}$
$\mathbf{Sl} \rr{Sl}$	$\boxed{\Downarrow} \rrh{Sl}$	$\mathbf{Sl} \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Sl\}}$
$\mathbf{Sl}' \rr{Slp}$	$\boxed{\Uparrow} \rrh{Slp}$	$\mathbf{Sl}' \boxed{\Uparrow} \text{\texttt{\textbackslash textRubik}\{Slp\}}$
$\mathbf{Sr} \rr{Sr}$	$\boxed{\Uparrow} \rrh{Sr}$	$\mathbf{Sr} \boxed{\Uparrow} \text{\texttt{\textbackslash textRubik}\{Sr\}}$
$\mathbf{Sr}' \rr{Srp}$	$\boxed{\Downarrow} \rrh{Srp}$	$\mathbf{Sr}' \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{Srp\}}$
$\mathbf{Sf} \rr{Sf}$	$\boxed{\mathbf{Sf}} \rrh{Sf}$	$\boxed{\mathbf{Sf}} \text{\texttt{\textbackslash textRubik}\{Sf\}}$
$\mathbf{Sf}' \rr{Sfp}$	$\boxed{\mathbf{Sf}'} \rrh{Sfp}$	$\boxed{\mathbf{Sf}'} \text{\texttt{\textbackslash textRubik}\{Sfp\}}$
$\mathbf{Sb} \rr{Sb}$	$\boxed{\mathbf{Sb}} \rrh{Sb}$	$\boxed{\mathbf{Sb}} \text{\texttt{\textbackslash textRubik}\{Sb\}}$
$\mathbf{Sb}' \rr{Sbp}$	$\boxed{\mathbf{Sb}'} \rrh{Sbp}$	$\boxed{\mathbf{Sb}'} \text{\texttt{\textbackslash textRubik}\{Sbp\}}$
$\mathbf{E} \rr{E}$	$\boxed{\Rightarrow} \rrh{E}$	$\mathbf{E} \boxed{\Rightarrow} \text{\texttt{\textbackslash textRubik}\{E\}}$
$\mathbf{E}' \rr{Ep}$	$\boxed{\Leftarrow} \rrh{Ep}$	$\mathbf{E}' \boxed{\Leftarrow} \text{\texttt{\textbackslash textRubik}\{Ep\}}$
$\mathbf{M} \rr{M}$	$\boxed{\Downarrow} \rrh{M}$	$\mathbf{M} \boxed{\Downarrow} \text{\texttt{\textbackslash textRubik}\{M\}}$

$\mathbf{M}' \rr{Mp}$	$\boxed{\uparrow\uparrow} \rrh{Mp}$	$\mathbf{M}' \boxed{\uparrow\uparrow} \text{\textRubik{Mp}}$
$\mathbf{S} \rr{S}$	$\boxed{\mathbf{S}} \rrh{S}$	$\boxed{\mathbf{S}} \text{\textRubik{S}}$
$\mathbf{S}' \rr{Sp}$	$\boxed{\mathbf{S}'} \rrh{Sp}$	$\boxed{\mathbf{S}'} \text{\textRubik{Sp}}$
$\mathbf{x} \rr{x}$	$\boxed{\mathbf{x}} \rrh{x}$	$\boxed{\mathbf{x}} \text{\textRubik{x}}$
$\mathbf{x}' \rr{xp}$	$\boxed{\mathbf{x}'} \rrh{xp}$	$\boxed{\mathbf{x}'} \text{\textRubik{xp}}$
$\mathbf{y} \rr{y}$	$\boxed{\mathbf{y}} \rrh{y}$	$\boxed{\mathbf{y}} \text{\textRubik{y}}$
$\mathbf{y}' \rr{yp}$	$\boxed{\mathbf{y}'} \rrh{yp}$	$\boxed{\mathbf{y}'} \text{\textRubik{yp}}$
$\mathbf{z} \rr{z}$	$\boxed{\mathbf{z}} \rrh{z}$	$\boxed{\mathbf{z}} \text{\textRubik{z}}$
$\mathbf{z}' \rr{zp}$	$\boxed{\mathbf{z}'} \rrh{zp}$	$\boxed{\mathbf{z}'} \text{\textRubik{zp}}$
$\mathbf{u} \rr{u}$	$\boxed{\mathbf{u}} \rrh{u}$	$\boxed{\mathbf{u}} \text{\textRubik{u}}$
$\mathbf{u}' \rr{up}$	$\boxed{\mathbf{u}'} \rrh{up}$	$\boxed{\mathbf{u}'} \text{\textRubik{up}}$
$\mathbf{d} \rr{d}$	$\boxed{\mathbf{d}} \rrh{d}$	$\boxed{\mathbf{d}} \text{\textRubik{d}}$
$\mathbf{d}' \rr{dp}$	$\boxed{\mathbf{d}'} \rrh{dp}$	$\boxed{\mathbf{d}'} \text{\textRubik{dp}}$
$\mathbf{l} \rr{l}$	$\boxed{\mathbf{l}} \rrh{l}$	$\boxed{\mathbf{l}} \text{\textRubik{l}}$
$\mathbf{l}' \rr{lp}$	$\boxed{\mathbf{l}'} \rrh{lp}$	$\boxed{\mathbf{l}'} \text{\textRubik{lp}}$
$\mathbf{r} \rr{r}$	$\boxed{\mathbf{r}} \rrh{r}$	$\boxed{\mathbf{r}} \text{\textRubik{r}}$
$\mathbf{r}' \rr{rp}$	$\boxed{\mathbf{r}'} \rrh{rp}$	$\boxed{\mathbf{r}'} \text{\textRubik{rp}}$
$\mathbf{f} \rr{f}$	$\boxed{\mathbf{f}} \rrh{f}$	$\boxed{\mathbf{f}} \text{\textRubik{f}}$
$\mathbf{f}' \rr{fp}$	$\boxed{\mathbf{f}'} \rrh{fp}$	$\boxed{\mathbf{f}'} \text{\textRubik{fp}}$
$\mathbf{b} \rr{b}$	$\boxed{\mathbf{b}} \rrh{b}$	$\boxed{\mathbf{b}} \text{\textRubik{b}}$
$\mathbf{b}' \rr{bp}$	$\boxed{\mathbf{b}'} \rrh{bp}$	$\boxed{\mathbf{b}'} \text{\textRubik{bp}}$

9.9.1 Randelshofer notation

$\mathbf{CR} \rr{CR}$	$\boxed{\mathbf{CR}} \rrh{CR}$	$\boxed{\mathbf{CR}} \text{\textRubik{CR}}$
$\mathbf{CR}' \rr{CRp}$	$\boxed{\mathbf{CR}'} \rrh{CRp}$	$\boxed{\mathbf{CR}'} \text{\textRubik{CRp}}$

$\mathbf{CL} \rr{\mathbf{CL}}$	$[\mathbf{CL}] \rrh{\mathbf{CL}}$	$[\mathbf{CL}] \backslash \text{Rubik}\{\mathbf{CL}\}$
$\mathbf{CL}' \rr{\mathbf{CLp}}$	$[\mathbf{CL}'] \rrh{\mathbf{CLp}}$	$[\mathbf{CL}'] \backslash \text{Rubik}\{\mathbf{CLp}\}$
$\mathbf{CU} \rr{\mathbf{CU}}$	$[\mathbf{CU}] \rrh{\mathbf{CU}}$	$[\mathbf{CU}] \backslash \text{Rubik}\{\mathbf{CU}\}$
$\mathbf{CU}' \rr{\mathbf{CUp}}$	$[\mathbf{CU}'] \rrh{\mathbf{CUp}}$	$[\mathbf{CU}'] \backslash \text{Rubik}\{\mathbf{CUp}\}$
$\mathbf{CD} \rr{\mathbf{CD}}$	$[\mathbf{CD}] \rrh{\mathbf{CD}}$	$[\mathbf{CD}] \backslash \text{Rubik}\{\mathbf{CD}\}$
$\mathbf{CD}' \rr{\mathbf{CDp}}$	$[\mathbf{CD}'] \rrh{\mathbf{CDp}}$	$[\mathbf{CD}'] \backslash \text{Rubik}\{\mathbf{CDp}\}$
$\mathbf{CF} \rr{\mathbf{CF}}$	$[\mathbf{CF}] \rrh{\mathbf{CF}}$	$[\mathbf{CF}] \backslash \text{Rubik}\{\mathbf{CF}\}$
$\mathbf{CF}' \rr{\mathbf{CFp}}$	$[\mathbf{CF}'] \rrh{\mathbf{CFp}}$	$[\mathbf{CF}'] \backslash \text{Rubik}\{\mathbf{CFp}\}$
$\mathbf{CB} \rr{\mathbf{CB}}$	$[\mathbf{CB}] \rrh{\mathbf{CB}}$	$[\mathbf{CB}] \backslash \text{Rubik}\{\mathbf{CB}\}$
$\mathbf{CB}' \rr{\mathbf{CBp}}$	$[\mathbf{CB}'] \rrh{\mathbf{CBp}}$	$[\mathbf{CB}'] \backslash \text{Rubik}\{\mathbf{CBp}\}$
$\mathbf{MR} \rr{\mathbf{MR}}$	$\boxed{\uparrow\uparrow} \rrh{\mathbf{MR}}$	$\mathbf{MR} \boxed{\uparrow\uparrow} \backslash \text{textRubik}\{\mathbf{MR}\}$
$\mathbf{MR}' \rr{\mathbf{MRp}}$	$\boxed{\downarrow\downarrow} \rrh{\mathbf{MRp}}$	$\mathbf{MR}' \boxed{\downarrow\downarrow} \backslash \text{textRubik}\{\mathbf{MRp}\}$
$\mathbf{ML} \rr{\mathbf{ML}}$	$\boxed{\downarrow\downarrow} \rrh{\mathbf{ML}}$	$\mathbf{ML} \boxed{\downarrow\downarrow} \backslash \text{textRubik}\{\mathbf{ML}\}$
$\mathbf{ML}' \rr{\mathbf{MLp}}$	$\boxed{\uparrow\uparrow} \rrh{\mathbf{MLp}}$	$\mathbf{ML}' \boxed{\uparrow\uparrow} \backslash \text{textRubik}\{\mathbf{MLp}\}$
$\mathbf{MU} \rr{\mathbf{MU}}$	$\boxed{\Leftarrow} \rrh{\mathbf{MU}}$	$\mathbf{MU} \boxed{\Leftarrow} \backslash \text{textRubik}\{\mathbf{MU}\}$
$\mathbf{MU}' \rr{\mathbf{MUp}}$	$\boxed{\Rightarrow} \rrh{\mathbf{MUp}}$	$\mathbf{MU}' \boxed{\Rightarrow} \backslash \text{textRubik}\{\mathbf{MUp}\}$
$\mathbf{MD} \rr{\mathbf{MD}}$	$\boxed{\Rightarrow} \rrh{\mathbf{MD}}$	$\mathbf{MD} \boxed{\Rightarrow} \backslash \text{textRubik}\{\mathbf{MD}\}$
$\mathbf{MD}' \rr{\mathbf{MDp}}$	$\boxed{\Leftarrow} \rrh{\mathbf{MDp}}$	$\mathbf{MD}' \boxed{\Leftarrow} \backslash \text{textRubik}\{\mathbf{MDp}\}$
$\mathbf{MF} \rr{\mathbf{MF}}$	$\boxed{\mathbf{MF}} \rrh{\mathbf{MF}}$	$\boxed{\mathbf{MF}} \backslash \text{textRubik}\{\mathbf{MF}\}$
$\mathbf{MF}' \rr{\mathbf{MFp}}$	$\boxed{\mathbf{MF}'} \rrh{\mathbf{MFp}}$	$\boxed{\mathbf{MF}'} \backslash \text{textRubik}\{\mathbf{MFp}\}$
$\mathbf{MB} \rr{\mathbf{MB}}$	$\boxed{\mathbf{MB}} \rrh{\mathbf{MB}}$	$\boxed{\mathbf{MB}} \backslash \text{textRubik}\{\mathbf{MB}\}$
$\mathbf{MB}' \rr{\mathbf{MBp}}$	$\boxed{\mathbf{MB}'} \rrh{\mathbf{MBp}}$	$\boxed{\mathbf{MB}'} \backslash \text{textRubik}\{\mathbf{MBp}\}$
$\mathbf{SR} \rr{\mathbf{SR}}$	$\boxed{\uparrow\uparrow} \rrh{\mathbf{SR}}$	$\mathbf{SR} \boxed{\uparrow\uparrow} \backslash \text{textRubik}\{\mathbf{SR}\}$
$\mathbf{SR}' \rr{\mathbf{SRp}}$	$\boxed{\downarrow\downarrow} \rrh{\mathbf{SRp}}$	$\mathbf{SR}' \boxed{\downarrow\downarrow} \backslash \text{textRubik}\{\mathbf{SRp}\}$
$\mathbf{SL} \rr{\mathbf{SL}}$	$\boxed{\downarrow\downarrow} \rrh{\mathbf{SL}}$	$\mathbf{SL} \boxed{\downarrow\downarrow} \backslash \text{textRubik}\{\mathbf{SL}\}$

SL' $\backslash rr\{SLp\}$	 $\backslash rrh\{SLp\}$	SL'  $\backslash textRubik\{SLp\}$
SU $\backslash rr\{SU\}$	 $\backslash rrh\{SU\}$	SU  $\backslash textRubik\{SU\}$
SU' $\backslash rr\{SUP\}$	 $\backslash rrh\{SUP\}$	SU'  $\backslash textRubik\{SUP\}$
SD $\backslash rr\{SD\}$	 $\backslash rrh\{SD\}$	SD  $\backslash textRubik\{SD\}$
SD' $\backslash rr\{SDp\}$	 $\backslash rrh\{SDp\}$	SD'  $\backslash textRubik\{SDp\}$
SF $\backslash rr\{SF\}$	 $\backslash rrh\{SF\}$	SF  $\backslash textRubik\{SF\}$
SF' $\backslash rr\{SFp\}$	 $\backslash rrh\{SFp\}$	SF'  $\backslash textRubik\{SFp\}$
SB $\backslash rr\{SB\}$	 $\backslash rrh\{SB\}$	SB  $\backslash textRubik\{SB\}$
SB' $\backslash rr\{SBp\}$	 $\backslash rrh\{SBp\}$	SB'  $\backslash textRubik\{SBp\}$
TR $\backslash rr\{TR\}$	 $\backslash rrh\{TR\}$	TR  $\backslash textRubik\{TR\}$
TR' $\backslash rr\{TRp\}$	 $\backslash rrh\{TRp\}$	TR'  $\backslash textRubik\{TRp\}$
TL $\backslash rr\{TL\}$	 $\backslash rrh\{TL\}$	TL  $\backslash textRubik\{TL\}$
TL' $\backslash rr\{TLp\}$	 $\backslash rrh\{TLp\}$	TL'  $\backslash textRubik\{TLp\}$
TU $\backslash rr\{TU\}$	 $\backslash rrh\{TU\}$	TU  $\backslash textRubik\{TU\}$
TU' $\backslash rr\{TUp\}$	 $\backslash rrh\{TUp\}$	TU'  $\backslash textRubik\{TUp\}$
TD $\backslash rr\{TD\}$	 $\backslash rrh\{TD\}$	TD  $\backslash textRubik\{TD\}$
TD' $\backslash rr\{TDp\}$	 $\backslash rrh\{TDp\}$	TD'  $\backslash textRubik\{TDp\}$
TF $\backslash rr\{TF\}$	 $\backslash rrh\{TF\}$	TF  $\backslash textRubik\{TF\}$
TF' $\backslash rr\{TFp\}$	 $\backslash rrh\{TFp\}$	TF'  $\backslash textRubik\{TFp\}$
TB $\backslash rr\{TB\}$	 $\backslash rrh\{TB\}$	TB  $\backslash textRubik\{TB\}$
TB' $\backslash rr\{TBp\}$	 $\backslash rrh\{TBp\}$	TB'  $\backslash textRubik\{TBp\}$

9.10 The rubikfont

For hieroglyph-related text we use the standard Computer Modern Sans (cmss) bold extended (bx) 10pt font for upper-case letters, and the 8pt footnote size for lower-case letters (see Section 20.3 for details). This font (rubikfont) and the ‘prime’ symbol (rubikprime) can be easily changed by ‘renewing’ the three

commands there.

For example, to change to the somewhat ‘lighter’ semi-bold extended (sbx) CM Sans (cmss) form one can simply include the following in the preamble (the FNS suffix stands for ‘footnotesize’):

```
\makeatletter
\renewcommand{\@rubikfont}{\fontsize{10}{12pt}\usefont{T1}{cmss}{sbx}{n}}
\renewcommand{\@rubikfontFNS}{\fontsize{8}{12pt}\usefont{T1}{cmss}{sbx}{n}}
\makeatother
```

The ‘rubikprime’ symbol

We currently use the apostrophe for the prime symbol (see Section 20.3), since the maths `\prime` seems to be a bit too faint (especially since we need to use the ‘scriptstyle’ size in this setting). However, users can easily make the Rubik bundle use the maths prime instead, by loading the following in the preamble.

```
\makeatletter
\renewcommand{\@rubikprime}{\raisebox{1.2pt}{\ensuremath{\scriptstyle\prime}}}}
\makeatother
```

10 Draw commands

A `\Draw..` command typesets either a cubie, cube or face using parameters set or defined via previous parameter-allocation commands (e.g., colours, dimensions etc).

It is important to distinguish between the RUBIKCUBE package `\Draw..` commands (with an upper-case D) and TikZ `\draw..` commands (with a lowercase d). Rubik `\Draw..` commands are implemented by the TikZ `\draw..` commands, and consequently `\Draw..` commands can only be used *inside* a TikZ picture environment—and hence they can also be used safely in conjunction with the `\ShowCube` command, which itself uses a TikZ picture environment. See also Section 10.1 below.

There are six types of `\Draw..` commands, as follows:

```
\DrawCubie..
\DrawRubikCube..
\DrawRubikCubeSidebar..
\DrawRubikFace..
\DrawRubikFlat..
\DrawNCube..
```

Note that the former `\DrawRubikLayer..`, `\DrawCube..`, `\DrawFace..` commands are now deprecated, since they have been superseded by more versatile and intuitive commands (see Section 15).

10.1 \Draw error message

If a `\Draw..` command is used *outside* a TikZ picture environment, then L^AT_EX issues an “Undefined control sequence” error message, indicating that it is trying to draw something using an undefined TikZ `\draw` command¹⁰.

This is because all Rubik `\Draw..` commands achieve their effects by implementing a series of TikZ `\draw..` and other commands, all of which need to be inside a `tikzpicture` environment.

For example, if the command `\DrawRubikCubeF` is used without a surrounding TikZ picture environment, then something similar to the following error message will be generated.

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

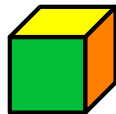
10.2 DrawCubie commands

`\DrawCubieXY` 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 this command takes three xyz-ordered colour parameter arguments. Consequently the `\DrawCubie` command has 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.



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

Since the front face is 1 unit wide and the 2D width of the side approx 1/3 unit, and the scale-factor = 1, then the minipage width required for the cubie image = $(1.33 \times 1) = 1.33\text{cm}$.

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

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

as shown in the following example.

¹⁰Note that the TikZ `\draw` command uses a lower-case ‘d’, while all RUBIKCUBE commands start with an upper-case letter.

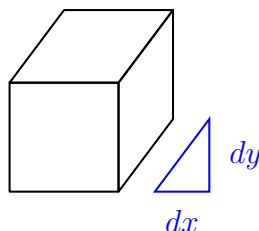
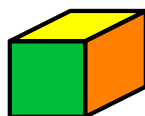


Figure 3: Cubiedy and Cubiedx parameters



```
\ShowCube{1.7cm}{1}{%
\Cubiedy{0.4}
\Cubiedx{0.8}
\DrawCubieRU{0}{Y}{G}
}
```

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 13). The default values of `\Cubiedy` and `\Cubiedx` are 0.4.

10.3 textCubie commands

`\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 pre-set for text use.

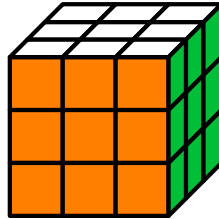
10.4 DrawRubikCube commands

`\DrawRubikCubeXY`
`\DrawRubikCubeF`
`\DrawRubikCubeSF`

This command draws Rubik cubes in one of four oblique orientations or configurations as denoted by the following terminal XY viewing-direction codes: RU (RightUp), RD (RightDown), LU (LeftUp), LD (LeftDown); two additional terminal codes are F (Flat) and SF (Semi-Flat). For example, the command

`\DrawRubikCubeRU`

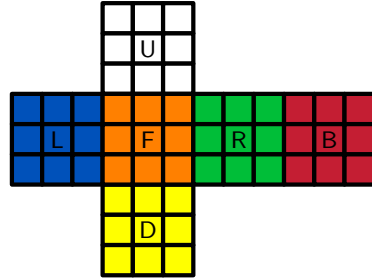
will draw a Rubik cube as viewed from the RightUp direction (RU), as shown in the following figure.



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

`\DrawRubikCubeF`

This command draws the completely flat (F) format of the cube, as shown in the following example.



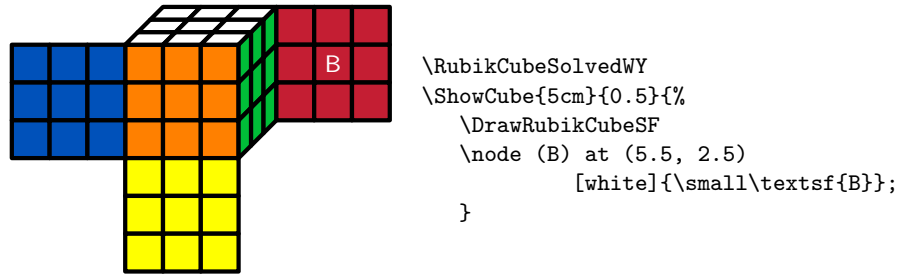
```
\RubikCubeSolvedWY
\ShowCube{5cm}{0.4}{\DrawRubikCubeF}
```

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 (remember TikZ commands require a terminal semi-colon ;).

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

`\DrawRubikCubeSF`

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



Note that even in this configuration it is straight-forward to write text on the graphic, since the 2D 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 coordinate-grid is at the bottom left corner of the FRONT face (the orange face here), the (x, y) coordinates of the centre of the red BACK face are easily determined to be $(5.5, 2.5)$.

10.5 DrawRubikFace.. commands

```

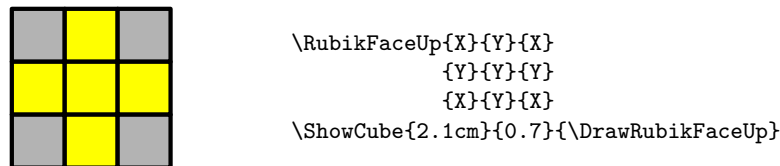
\DrawRubikFaceUp
\DrawRubikFaceDown
\DrawRubikFaceLeft
\DrawRubikFaceRight
\DrawRubikFaceFront
\DrawRubikFaceBack
\DrawRubikFaceUpSide
\DrawRubikFaceDownSide
\DrawRubikFaceLeftSide
\DrawRubikFaceRightSide
\DrawRubikFaceFrontSide
\DrawRubikFaceBackSide

```

These commands draw the current state of a specified face (e.g., `\DrawRubikFaceUp`), or the face and all the associated sidebars (e.g., `\DrawRubikFaceUpSide`). These commands do NOT take any arguments—for code see Section 20.15.

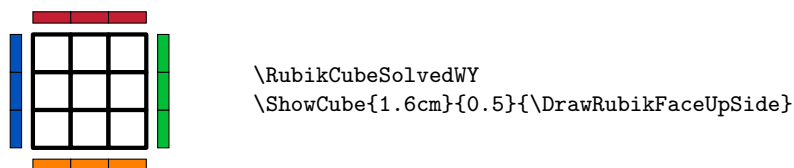
NOTE: These commands replace the earlier `\DrawFace...` commands (see Section 15).

For example, a simple way to show the yellow-cross configuration in the UP face would be to first define the colours using the `\RubikFaceUp` command, and then draw the UP face using the `\DrawRubikFaceUp` command, as follows:



10.6 Sidebars & DrawRubikFaceXSide commands

In the next example we use the `\DrawRubikFaceUpSide` command to draw the UP face and all its sidebars in a cube having a 'solved' WY (White opposite Yellow) configuration.



Short-hand versions: For convenience each of these commands has an equivalent short-hand version generated by using just the first letter of the face name and

(where appropriate) the first letter of the word Side. For example,
`\DrawRubikFaceR` \equiv `\DrawRubikFaceRight`,
`\DrawRubikFaceRS` \equiv `\DrawRubikFaceRightSide`, etc.

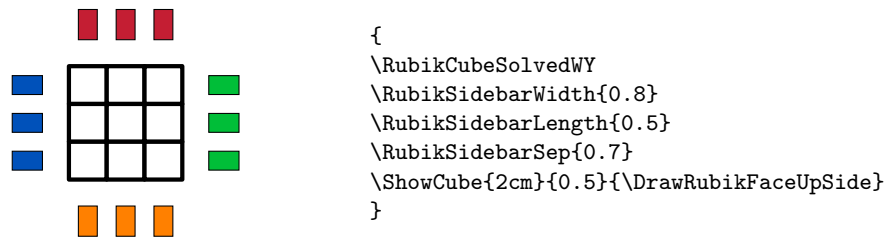
10.7 Sidebar parameters

`\RubikSidebarWidth` The default values (size) of the sidebars are as follows: width (0.3), length(1) and
`\RubikSidebarLength` separation from the square face (0.3) —see Section 20.16 for the code. Note that
`\RubikSidebarSep` 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.

<code>\RubikSidebarWidth{}</code>	(default = 0.3)
<code>\RubikSidebarLength{}</code>	(default = 1.0)
<code>\RubikSidebarSep{}</code>	(default = 0.3)

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. Alternatively, one can keep the effect local using braces (see below).

In the following example, we show the effect on the UP face and sidebars of a normally solved (WY) cube after dramatically changing the sidebar width, length and separation from the default values—compare with the previous image. For convenience, we have used a pair of braces to keep the effect local to this example.



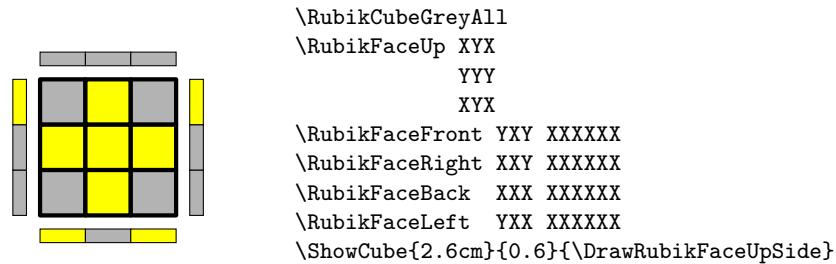
Note also that changing the sidebar-width or sidebar-separation values may well also change the surrounding white-space (use `\fbox` to visualise this) and may therefore require some fine-tuning of the minipage width setting in order to optimise appearance.

10.8 \NoSidebar command

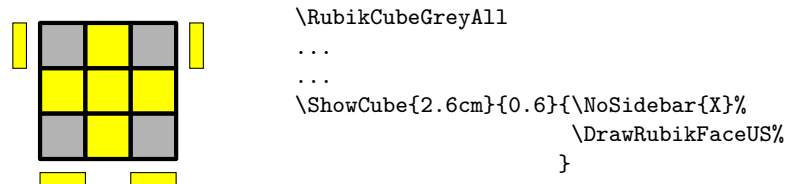
`\NoSidebar` The `\NoSidebar{<colour-code>}` command (which takes a single colour code argument) allows the user to disable the drawing of sidebars having a particular colour (for code see Section 20.16.1). Its action can be localised by placing the command inside an environment (e.g., inside the `\ShowCube` environment). Alternatively, the action of this command can be disabled simply by writing it with an empty argument, e.g., `\NoSidebar{}`.

This command is designed to facilitate the drawing of so-called OLL (Orientate Last Layer) configurations, which are typically rendered using the yellow face.

For example, the following figure uses the `\DrawRubikFaceUpSide` command to draw the commonly encountered OLL configuration known as the ‘yellow cross’ (the remaining four yellow facelets associated with this layer are shown as sidebars). In this example, we first define the colours for the whole cube (grey), and then redefine the colours for the UP face and its four adjacent faces. Finally we draw the UP face and sidebars; we also show an alternative way of writing the facelet colour codes (ie without using the curly brackets).



However, we can greatly improve the OLL image by disabling the drawing of all the grey (X) sidebars by using the `\NoSidebar{X}` command as follows (here we have placed the `\NoSidebar{X}` command inside the `\ShowCube` environment in order to limit its action locally). Note also that this time we have used the short-hand US (UpSide) version of the `\DrawRubikFaceUpSide` command.



10.9 Cube sidebars & DrawRubikCubeSidebar commands

Cube sidebars are drawn adjacent to cube edges which are defined by the two faces forming the edge. Thus the BR (Back-Right) sidebar is placed adjacent to the edge formed by the BACK and RIGHT faces.

Since the cube orientation (view direction; RU, RD, LU, LD) determines which sidebars are visible, the command for drawing the sidebar (`\DrawRubikCubeSidebar...`) also needs to incorporate the view direction. The command takes two mandatory arguments: the first is the pair of face codes defining the edge (XX); the second is the view direction, as follows:

```

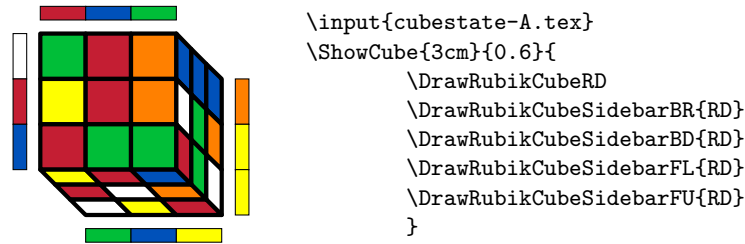
\DrawRubikCubeSidebarXX{<view direction>}
EXAMPLE: \DrawRubikCubeSidebarRB{LD}

```

Note that the pair of face codes are order *independent*, and hence can be written in any order, which makes remembering the commands very easy.

Note also that at present commands are only available for the eight sidebars which are parallel to X,Y axes, as these seem to be the most useful.

In the following example, we input a previously saved cube state (in the file `cubestate-A.tex`) and draw the cube and the four main sidebars (BR, BD, FL, FU) visible from the RD view direction.



10.10 DrawRubikFlat commands

```

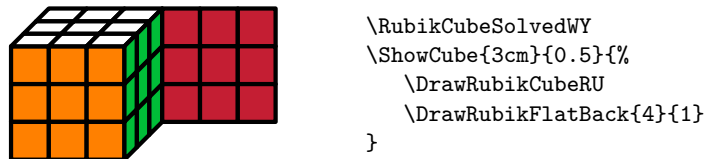
\DrawRubikFlatUp
\DrawRubikFlatDown
\DrawRubikFlatLeft
\DrawRubikFlatRight
\DrawRubikFlatFront
\DrawRubikFlatBack
```

The `\DrawRubikFlat.. $\langle x \rangle \langle y \rangle$` commands draw a ‘flat’ square representation of a specified face, located such that its bottom left corner is positioned at (x,y) . Each command (except `\DrawRubikFlatFront`) 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 (see Section 20.14 for the code).

These commands are designed to supplement the `\DrawRubikCube...` commands and allow hidden faces to be represented.

Note also that the `\DrawRubikFlatFront` 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.

USAGE: The following example uses the command `\DrawRubikFlatBack{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 4), we can position the lower/left corner of the BACK face at this point using the command `\DrawRubikFlatBack{4}{1}` as follows:

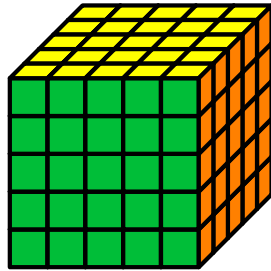


10.11 DrawNCube (NxNxN)

`\DrawNCubeAll` An ‘NCube’ is a solved $N \times N \times N$ 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}}`

11 \ShowSequence command

`\ShowSequence`
`\ShowSequenceF`
`\ShowSequencef`

The `\ShowSequence{<separator>}{<font-code>}{<sequence>}` command typesets a comma-separated sequence of rotation codes—for code see Section 20.5. Appending an ‘F’ to the command-name (`\ShowSequenceF`) results in an fbox around the whole output (cf. the `\ShowCubeF` command). Appending a lower-case ‘f’ to the command-name (`\ShowSequencef`) generates fboxes around *each element* in the output (these two forms can be helpful when checking white space).

The `\ShowSequence` command takes three mandatory arguments: the first is the separator (#1), the second is the font or style code (#2), and third is a comma-separated sequence of Rubik rotation codes (#3).

The separator (e.g., comma) used for typesetting the sequence can be specified (or just omitted—i.e., an empty bracket); the sequence can be either a named sequence (i.e., encoded as a macro) or just a comma separated sequence of rotation codes.

USAGE: The following command displays the rotation sequence F, R, U, Rp, Up, using the `\rr` encoding and comma & space separated.

`\ShowSequence{,\ }{\rr}{F,R,U,Rp,Up} → F, R, U, R', U'`













Remember that if you want a very long sequence to break automatically at the line-ends, then you need to include at least one space between the sequence elements, either with or without a comma; for this the separator argument needs to include a space, i.e., something like `{,\ }` or `{\ }` or just `{ }` perhaps.

For example, the following commands typeset the comma-separated rotation sequence U,D,Lp,R using different separators and fonts. For convenience, we start by encoding the sequence as the macro `\myseq`.

`\newcommand{\myseq}{U,D,Lp,R}`

`\ShowSequence{,\ }{\texttt}{\myseq} → U,D,Lp,R`

```

\ShowSequence{,}{\rr}{\myseq} → U,D,L',R
\ShowSequence{,}{\rrh}{\myseq} →    
\ShowSequence{\ }{\rrh}{\myseq} →    
\ShowSequence{,\ }{\textRubik}{\myseq} → U  , D  , L'  , R 

```

11.1 Trailing digits

Note that the commands `\rr`, `\rrh`, `\Rubik` and `\textRubik` will fail for rotation codes which have a trailing digit, e.g., `R2`, `Dp3` (so-called ‘short’ codes), since the `\ShowSequence` macro currently only reads the whole string between pairs of commas (i.e., it does not *interpret* strings like `R2` → `R,R` etc.). However, if you just want to ‘see’ the text, then the standard L^AT_EX typewriter command `\texttt` will typeset the text correctly, as you would expect (but using the `tt` font of course).

A useful ‘work-around’ for this limitation is provided by the `\RubikRotation{}` command¹¹ (part of the RUBIKROTATION package), since this returns (via the Perl program `rubikrotation.pl`) an extended (‘long’) form of a given sequence in which any ‘short’ rotation codes are converted into their separate (atomic) long-form rotation codes; the associated string is `\SequenceLong`. In fact three different forms of the sequence are returned, as shown below.

For example, consider the following short-form sequence `L,R,D2,L3`, and denote it as ‘seqA’ as follows: `\newcommand{\seqA}{[seqA],L,R,D2,L3,<test>}`. In this case `D2,L3`, and the name ‘seqA’ fail to be typeset when using the `\rr` font with the `\ShowSequence` command (notice there are lots of commas with nothing between them), while `\texttt` does work, as follows:

```

\newcommand{\seqA}{[seqA],L,R,D2,L3,<test>}
\ShowSequence{,}{\rr}{\seqA} → ,L,R,,,
\ShowSequence{,}{\texttt}{\seqA} → [seqA],L,R,D2,L3,<test>

```

However, if we now run the command `\RubikRotation{\seqA}` we shall then have at our disposal the following four strings:

```

\SequenceInfo    = test
\SequenceName    = seqA
\SequenceShort   = L,R,D2,L3
\SequenceLong    = L,R,D,D,L,L,L

```

and therefore have full control over typesetting rotation sequences. This approach therefore offers sufficient flexibility for most purposes. For example, if we now write the command `\ShowSequence{,}{\rr}{\SequenceLong}` we obtain

```

\ShowSequence{,}{\rr}{\SequenceLong} → L,R,D,D,L,L,L

```

In practice, any trailing digit is converted (modulo 4) and expanded accordingly, the details being copied to the log-file. For example, if one writes the

¹¹Using the `--shell-escape` command-line option with the L^AT_EX engine—see Section 1.2.

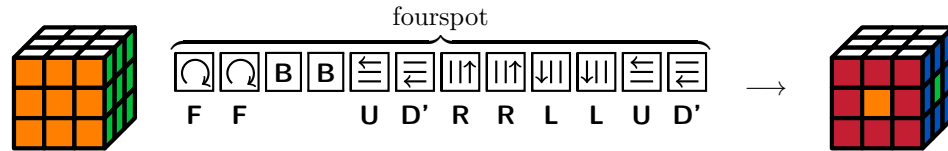
command `\RubikRotation{[test],R,D28978}`, then since $28978 \equiv 2 \pmod{4}$ then `\SequenceLong` will be returned containing the string `R,D,D`. The associated entries in the log-file are as follows:

```
...rotation R OK
...Expanding D28978 (28978 = 2 mod 4) ...
...rotation D OK (= Dp3)
...rotation D OK (= Dp3)
...writing new Rubik state to file rubikstateNEW.dat
...SequenceName = test
...SequenceShort = R,D28978
...SequenceLong = R,D,D
```

12 SequenceBrace commands

`\SequenceBraceA` The `\SequenceBraceX{<name>}{<sequence>}` command is a tool for displaying a
`\SequenceBraceB` named sequence using a brace. The trailing A denotes that the brace is placed
`\SequenceBraceAF` Above the sequence; the trailing B denotes the brace is Below the sequence. Ap-
`\SequenceBraceBF` pending an ‘F’ to the command-name (e.g., `\SequenceBraceAF`) results in a sur-
rounding fbox (cf. the `\ShowCubeF` command). For the code see Section 20.6.
Thus `\SequenceBraceB{myseq}{U,D,L,R}` generates $\underbrace{U,D,L,R}_{\text{myseq}}$.

A typical example of its use might be:



which was generated by the following code, showing that the `\ShowSequence` command can be used as an argument for the `\SequenceBraceA` command:

```
\newcommand{\fourspot}{[fourspot],F2,B2,U,Dp,R2,L2,U,Dp}%
\noindent%
\RubikCubeSolvedWY%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
\RubikRotation{\fourspot}%
\quad\SequenceBraceA{\SequenceName}{%
\ShowSequence{}{\Rubik}{\SequenceLong}}%
\quad$\longrightarrow$\quad%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
```

Note (1) that the ‘fourspot’ listing is included in the RUBIKPATTERNS package, and (2) the `\RubikRotation` command requires using the `--shell-escape` command-line option with the \LaTeX engine—see Section 1.2 for details.

13 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 (i.e., in our own `\ShowCube` environment).

In order to facilitate using the standard TikZ ‘draw’ commands the graphic grid origin of Rubik cube images is located at the bottom left corner of the FRONT face (see also Section 4 for details of the cube’s coordinate system). Similarly, single face images (e.g., drawn using the `\DrawRubikFace...` or `\DrawRubikFlat...` commands etc.) and also Sidebars, have their grid origin at the bottom left corner of the face. Consequently the start and finish coordinates for any arrow or line are easy to determine.

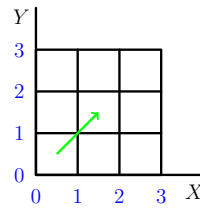
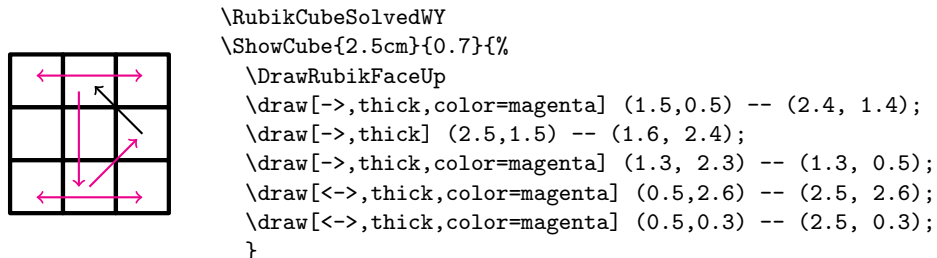


Figure 4: Grid showing the positive coordinates associated with FRONT face of a cube image, or of a face-only image.

For example, Figure 4 shows a green arrow drawn from the centre of the lower-left cubie (0.5,0.5) to the centre of middle cubie (1.5,1.5). To do this we just include the following TikZ command (remember that TikZ commands require a terminal semicolon):

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

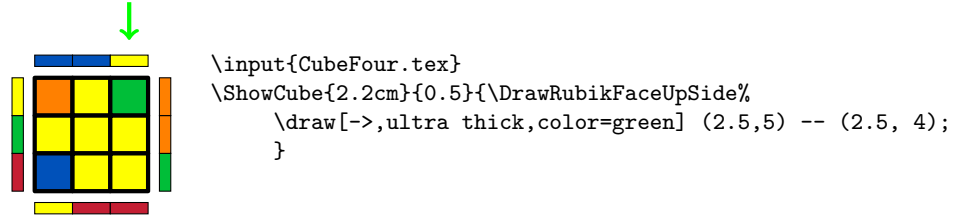
The following example shows the cubie movement in the UP face generated by the rotation sequence **FRUR’U’F’**. The magenta arrows indicate movement *with* cubie rotations, while the black arrow indicates movement *without* rotation. This example also highlights the fact that when there are several arrows,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



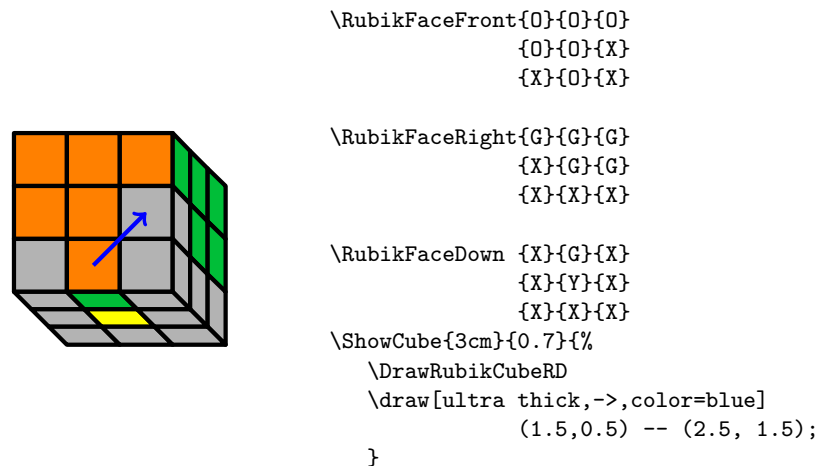
Since the coordinates shown in Figure 4 extend outwards in all directions, they

can also be used as a guide for drawing arrows (or other structures) outside this 3x3 ‘face’ square. The origin is at lower left corner of the face.

In the following example, we input a Rubik cube configuration (previously saved as the file `CubeFour.tex` (see the RUBIKROTATION package documentation for details)¹², and draw an arrow to highlight a yellow side facelet.

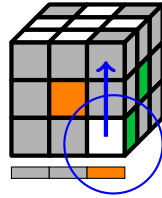


The following example shows an arrow on the Rubik cube. The origin of coordinates is at the bottom left corner of the FRONT face (see Section 4).



In the following example we use a blue circle to highlight a corner cubie to be rotated into the top layer. Note we also use the command `\DrawRubikCubeSidebarFD{RU}` to draw the sidebar along the FD (Front-Down) edge, and show the colour of the hidden facelet of the corner-cubie.

¹²See also the ‘SaveRubikState’ example in the file `RubikExamples.pdf`.



```

\RubikCubeGreyWY
\RubikFaceUp{X}{W}{X}
    {W}{W}{W}
    {W}{W}{X}
\RubikFaceDown{X}{X}{O}{X}{Y}{X}{X}{X}{X}%
\RubikSliceBottomR{X}{X}{W}{G}{X}{X}
\ShowCube{2.5cm}{0.5}{%
    \DrawRubikCubeRU
    \DrawRubikCubeSideBarFD{RU}
    \draw[ultra thick,->,color=blue]
        (2.5,0.5) -- (2.5, 2.5);
    \draw [color=blue, thick] (2.7, 0.3) circle (1.3);
}%

```

14 Final example

We now present, as a final example, the code used to draw the front page figure¹³. This code uses the `\RubikRotation` command (from the RUBIKROTATION package), and therefore the L^AT_EX engine needs to be run using the `--shell-escape` command-line switch (see Section 1.2 for details).



```

\noindent\hfil%
\RubikCubeSolvedWY%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
\quad\ShowCube{1.6cm}{0.4}{%
    \DrawRubikFaceUpSide%
    \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);
}%
\RubikRotation{F,R,U,Rp,Up,Fp}%
\quad\ShowSequence{}{\Rubik}{\SequenceLong}\quad$\longrightarrow$%
\ShowCube{1.6cm}{0.4}{\DrawRubikFaceUpSide}%
\hfil

```

¹³This is a well-known sequence of order 6 used to cycle three edge cubies; it is used to generate the 'cross' configuration in the final layer when solving the cube. Here we are performing the sequence on a 'solved' cube, since this allows you to see how the three edge cubies move, and either flip (magenta arrows) or do not flip (black arrow).

14.1 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}
\ShowSequence{,}{\Rubik}{\SequenceLong} \ \ \ $\longrightarrow$
\ShowCube{2cm}{0.4}{\DrawRubikFaceUpSide}
```

with the following commands:

```
\Rubik{F}\Rubik{R}\Rubik{U}\Rubik{Rp}\Rubik{Up}\Rubik{Fp}
\ \ \ $\longrightarrow$
\RubikFaceUp WWB WWOWRB
\RubikFaceBack RGG XXXXXX
\RubikFaceLeft RBO XXXXXX
\RubikFaceFront GW0 XXXXXX
\RubikFaceRight WWW XXXXXX
\quad\ShowCube{1.6cm}{0.4}{\DrawRubikFaceUpSide}
\hfil
```

15 Deprecated commands

The \DrawRubikLayerFace... and \DrawRubikLayerSide... are now deprecated; they were found to be confusing since (a) they both drew faces *and* took colour arguments for facelets, and (b) they did not update the internal colour state of a cube or face—i.e., their colouring was simply a local ‘painting’ action without memory. They have both been superseded by the more versatile \DrawRubikFace... commands (see Section 10.5).

The \RubikSide... commands are also deprecated, since they duplicated some of the function of the \RubikFace... commands.

The earlier \DrawFace... (v4) and \DrawFlat... (v3) commands are also deprecated since they lacked the Rubik or Two keyword (see Sections 3.1 and 10.5).

Summary of all deprecated commands (and their current versions) since v3.

\DrawRubikCubeFlat	→	\DrawRubikCubeSF (Semi-Flat)
\DrawRubikFlat	→	\DrawRubikCubeF (Flat)
\DrawFace...	→	\DrawRubikFace...
\DrawFlat...	→	\DrawRubikFlat...
\DrawFlat...Side	→	\DrawRubikFace...Side
\DrawRubikLayerFace...	→	\DrawRubikFace...
\DrawRubikLayerSide...	→	\DrawRubikFace...

16 Known limitations

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

- Note that the rotation hieroglyphs are optimised for a 10pt font and do not scale with document font size. However, they do work well in conjunction with the standard 11pt and 12pt document fonts sizes. Nevertheless, the font size can of course be changed by renewing the font command (see Section 9.10 for details).
- The sidebars cannot be arbitrarily positioned (note: hidden faces can be arbitrarily positioned).

17 Change history

- Version 5 (February 2018)
 - Removed some now unnecessary commands (see Section 15) and made some of the internal code a bit more efficient.
 - Added two new ‘grey’ commands: `\RubikCubeGreyWY` and `\RubikCubeGreyWB` (so as to complement the related `\RubikCubeSolvedXX` commands).
 - Bugfix: added a pair of containing braces around the `\ifthenelse..` command used by the `\ShowSequence` command (for code see Section 20.5). This fixed an occasional problem of a font not being contained.
 - Added missing lowercase cube ‘prime’ versions of whole cube rotation notation (`\u'`, `\d'`, `\l'`, `\r'`, `\f'`, `\b'`); see Section 9.6.
 - New `\NoSidebar` command for disabling the drawing of sidebars of a particular colour (see Section 10.8).
 - Implemented the terminal x, y position parameters for the `\DrawRubikFlatLeft` and `\DrawRubikFlatRight` commands; all the `\DrawRubikFlat..` commands work correctly now (see Section 20.14).
- Version 4.0 (March 2017)
 - Improved documentation.
 - Improved inter-hieroglyph spacing and vertical position. The Computer Modern sans bold font (10/12pt) is used for the hieroglyphs and rotation codes (see Section 20.3 for details).
 - Improved the `\ShowCube` and `\ShowCubeF` macros (see Sections 6 and 20.4).
 - Additional notation for middle slice rotations (‘m’ notation), e.g., `\Rm`, `\Rm'` etc (see Sections 9.3 and 20.22).
 - Additional notation for whole cube rotations (‘c’ notation), e.g., `\Rc`, `\Rc'` etc (see Sections 9.6 and 20.22).
 - Added Randelshofer notation (the ‘CMST’ rotations), e.g., `\CR`, `\MR` etc (see Sections 9.9.1 and 20.23).
 - Six new commands for showing and annotating rotation sequences; the versions with a terminal ‘F’ also surround the object with an fbox to allow users to see the extent of any associated white space (see Sections 11 & 12):

```
\ShowSequence
\ShowSequenceF
\ShowSequencef
\SequenceBraceA
\SequenceBraceAF
\SequenceBraceB
\SequenceBraceBF
```

—A new command for setting up or allocating a ‘solved’ colour configuration. (see Section 8.3):

```
\RubikSolvedConfig
```

—A new command for setting up a ‘starter cube’ for which the *whole* cube is allocated the default ‘grey’ colour (see Section 8.5):

```
\RubikCubeGreyAll
```

—A new supporting RUBIKPATTERNS package has been added to the Rubik bundle. It is a small macro database of well-known named Rubik patterns and associated sequences (see Section 1.4).

- 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 9). 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 6 and 20.4).

— `\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 8.5). 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 (but see Section 15).

```
\DrawFlatUp
\DrawFlatDown
\DrawFlatLeft
```

```

\DrawFlatRight
\DrawFlatFront
\DrawFlatBack
\DrawFlatUpSide
\DrawFlatDownSide
\DrawFlatLeftSide
\DrawFlatRightSide
\DrawFlatFrontSide
\DrawFlatBackSide

```

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

—Fixed a conflict with the \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.

18 Acknowledgements

We 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 also thank Christian Tellechea for the `\@join{ }{ }` command (see Section 20.21.3), Christian Schröppel for help regarding the `forarray` package (see Section 20.5), Herbert Kociemba for helpful comments, and Robert Mařík for suggesting the `\NoSidebar{ }` command (see Section 10.8).

19 References

- Bartal P (2011). <http://tex.stackexchange.com/questions/34482/>
- Chen JJ (2004). Group theory and the Rubik’s cube. <http://www.math.harvard.edu/~jjchen/docs/rubik.pdf>
- Davis T (2006). Group theory via Rubik’s cube. <http://www.geometer.org/rubik/group.pdf>
- Demaine ED, Demaine ML, Eisenstat S, Lubiw A and Winslow A (2011). Algorithms for solving Rubik’s cubes. <http://www.arxiv.org/abs/1106.5736/>

- Duvoid T (2010). Méthode simple pour remonter le Rubik's cube.
<http://duvoid.fr/rubik/rubik-debutant-couleurs.pdf>
http://duvoid.fr/rubik/sources/notation_en.eps
<http://duvoid.fr/rubik/sources/rubik-debutant-couleurs.tex>
- Duvoid T (2011). Méthode avancée pour remonter le Rubik's cube.
<http://duvoid.fr/rubik/rubik-fridrich-couleurs.pdf>
<http://duvoid.fr/rubik/sources/rubik-fridrich-couleurs.tex>
- Feuersänger (2016). Manual for package PGFPLOTS. v 1.13 (2016/01/06), § 3.2.3, page 21. (pgfplots.pdf) <http://www.ctan.org/pkg/pgfplots>. [re: preventing extra white space]
- Fridrich website (Fridrich J). <http://www.ws.binghamton.edu/fridrich/>. See the useful 'notation' section on the 'Pretty patterns' webpage at <http://www.ws.binghamton.edu/fridrich/ptrns.html>.
- Frey AH and Singmaster D (1982). *Handbook of cubik math*, (Enslow Publishers, Inc.) (republished: 2010, Lutterworth Press, UK)
- Fung website (Fung A). Solving the Rubik's cube systematically. <http://alexfung.info/favorite/cube/cube.htm>
- Garfath-Cox, A (1981). *The cube*, (Bolden Publishing Co., East Molesey, Surrey) pp.32. [copy in British Library]
- Golomb SW (1981). Rubik's cube and a model of quark confinement. *Am. J. Phys.*; vol 49, pp 1030–1031.
- Golomb SW (1982). Rubik's cube and quarks: twists on the eight corner cells of Rubik's cube provide a model for many aspects of quark behaviour. *American Scientist*; 70, No 3 (May–June 1982), pp. 257–259. <http://www.jstor.org/stable/27851433>
- Gymrek M (2009). The mathematics of the Rubik's cube.
<http://web.mit.edu/sp.268/www/rubik.pdf>
- Harris D (2008). Speedsolving the cube. (Sterling Publishing Co. Inc., New York, USA.) pp. 166. [covers 2x2x2, 3x3x3, 4x4x4, 5x5x5 cubes]
- Harris website (Harris D). <http://www.cubestation.co.uk>
- Heise website (Heise R). Rubik's cube theory. <http://www.ryanheise.com/cube/theory.html>
- Hofstadter D (1981). Rubik cube. *Scientific American*; March issue.
- Hutchings M (2011). The mathematics of Rubik's cube (slide presentation).
<http://math.berkeley.edu/~hutching/rubik.pdf>

- Jelinek website (Jelinek J). Rubik's cube solution methods. <http://www.rubikscube.info/>
- Joyner D (2008). *Adventures in group theory: Rubik's cube, Merlin's machine and other mathematical toys*; pp 322. <http://www.mike.verdone.ca/media/rubiks.pdf>
- Kociemba website (Kociemba H). <http://www.kociemba.org/cube.htm> —for superflip see: <http://www.kociemba.org/math/oh.htm>
- Kriz I and Siegel P (2008). Rubik's cube-inspired puzzles demonstrate math's simple groups. *Scientific American*; July 2008
- Longridge website (Longridge M). The cube pattern archive. <http://www.cubeman.org>
- Randelshofer website (Randelshofer W). Pretty patterns. <http://www.randelshofer.ch/rubik/patterns/>
- Reid website (Reid M). <http://www.cflmath.com/Rubik>, for patterns see <http://www.cflmath.com/Rubik/patterns.html>
- Reid M. (1995). Superflip requires 20 face turns. (January 1995) <http://www.math.ucf.edu/~reid/Rubik/CubeLovers/> [cited from Rokicki *et al.*, 2013].
(Note: easier to use is the following html indexed version of the archive of the Cube-Lovers usenet group (1982–1997) <http://www.math.rwth-aachen.de/~Martin.Schoenert/Cube-Lovers/>)
- Rokicki T, Kociemba H, Davidson M and Dethridge J (2013). The diameter of the Rubik's cube is twenty. *SIAM. J. Discrete Math.*, 27, 1082–1105. (<http://tomas.rokicki.com/rubik20.pdf>)
- Roux website (Roux G). <http://www.grroux.free.fr>
- Rubik's cube. See Section on notation. http://en.wikipedia.org/wiki/Rubik's_Cube
- RuWix website (Ferenec D). <http://www.ruwix.com>. See the online Rubik's cube solver <http://www.ruwix.com/online-rubiks-cube-solver-program>.
- Scherphius website (Scherphius J). Jaap Puzzles website <http://www.jaapsch.net/puzzles/symmetr1.htm>
- Sher S. T-H. (2014). The new durable Rubik's cube (technical description). http://www.scf.usc.edu/~tsher/files/Rubiks_Cube.pdf [includes RGB colour specification]
- Singmaster D (1981). *Notes on Rubik's magic cube* (Harmondsworth, Eng., Penguin Books)

- Speedsolving website. <http://www.speedsolving.com/>
- Storer website (Storer JA). <http://www.cs.brandeis.edu/~storer/JimPuzzles/>
For Rubik cube, see: <http://www.cs.brandeis.edu/~storer/JimPuzzles/RUBIK/Rubik3x3x3.pdf>
For puzzle book, see: <http://www.cs.brandeis.edu/~storer/zzzJimPuzzles/JimPuzzlesBook.pdf>
- Tran R (2005). A mathematical approach to solving Rubik's cube. <http://www.math.ubc.ca/~cass/courses/m308/projects/rtran/rtran.pdf>
- Treep A and Waterman M (1987). Marc Waterman's Algorithm, Part 2. *Cubism For Fun* 15, p. 10 (Nederlandse Kubus Club) [cited from *Wikipedia* (Rubik's cube)]
- Vandenberg website (Vandenberg L). CUBEZONE <http://www.cubezone.be>
- WCA (2016). World Cube Association Regulations. See § 12 for notation. <http://www.worldcubeassociation.org/regulations.htm>

20 The code (rubikcube.sty)

The conventions we adopt regarding capital letters and the XYZ argument ordering are detailed in Section 3.

Note that it is important when using 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 white-space.

20.1 Package heading

```

1 \(*rubikcube)
2 \def\RCfileversion{5.0}%
3 \def\RCfiledate{2018/02/25}% February 25, 2018
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}}%

```

The package requires the Forarray package (see Section 20.5)—so we load it if not already loaded.

```

9 \@ifpackageloaded{forarray}{}{%
10  \typeout{---rubikcube requires the Forarray package.}%
11  \RequirePackage{forarray}}%

```

The package requires the IfThen package (see Section 20.5)—so we load it if not already loaded.

```

12 \ifpackageloaded{ifthen}{}{%
13   \typeout{---rubikcube requires the IfThen package.}%
14   \RequirePackage{ifthen}}%
\rubikcube First we create a suitable logo
15 \newcommand{\rubikcube}{\textsc{rubikcube}}%
16 \newcommand{\Rubikcube}{\textsc{Rubikcube}}%
```

20.2 Colours

We have adopted the following colour allocations—see Section 8 for details.

```

17 \definecolor{R}{HTML}{C41E33}%
18 \definecolor{G}{HTML}{00BE38}%
19 \definecolor{B}{HTML}{0051BA}%
20 \definecolor{Y}{HTML}{FFFF00}%
21 \colorlet{X}{black!30}% grey
22 \colorlet{O}{orange}%
23 \colorlet{W}{white}%
```

20.3 The rubikfont

`\@rubikfont` We define two fonts for text associated with the Rubik glyphs (both the ‘arrow’
`\@rubikfontFNS` glyphs and the ‘letter’ glyphs), namely, (1) Computer Modern Sans (cmss), bold
`\@rubikprime` extended (bx), normal shape (n) at 10/12pt, and (2) a footnotesize (FNS) version
 (8pt) for the lower-case letters [for cmss see Latex Companion (2004), p. 417 &
 p. 354¹⁴]. This has the effect of keeping the size of Rubik glyphs constant in the
 face of any changes in the document fonts. We make the baseline-skip values the
 same, since the ‘arrow’ glyphs generated by the `\Rubik` commands involve a single
 baseline-skip (for example, as with `\Rubik{D}`; see Section 20.21.13). We use the
 cmss font apostrophe as the ‘prime’ symbol (the user has the opportunity to use
 the maths `\prime` instead—see Section 9.10).

```

24 \newcommand{\@rubikfont}{\fontsize{10}{12pt}\usefont{T1}{cmss}{bx}{n}}
25 \newcommand{\@rubikfontFNS}{\fontsize{8}{12pt}\usefont{T1}{cmss}{bx}{n}}
26 \newcommand{\@rubikprime}{’}
```

20.4 ShowCube command

`\ShowCube` The macro `\ShowCube{<minipage width>}{<TikZ scale factor>}{<Draw.. cmd>}`
`\ShowCubeF` 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}`

¹⁴Note the typo in Table 7.5 (p. 354): the font-series code for the Sans semi-bold condensed form is ‘sbx’ (not sbc).

February 2017 (RWDN): We first require a new length variable (which will become the minipage-width), so we can add the length 1.6pt to it (this is the width of the TikZ ultra-thick line which is used to draw the Rubik cubes). In order for a width of an image made up of x units to be equal to $x \times (\text{scale-factor})$ we need to add an extra line-width (i.e., to include the right-hand edge).

```
27 \newlength{\@showcubewidth}%
```

We can now build the two macros. We set the `\fboxsep` value to zero.

```
28 \newcommand{\ShowCube}[3]{%
29   \setlength{\fboxsep}{0cm}%
30   \setlength{\@showcubewidth}{#1}%
31   \advance\@showcubewidth by 1.6pt\relax%
32   \begin{minipage}{\the\@showcubewidth}%
33   \centering%
34   \begin{tikzpicture}[scale=#2]%
35   #3%
36   \end{tikzpicture}%
37   \end{minipage}%
38 }%
39 \newcommand{\ShowCubeF}[3]{%
40   \setlength{\fboxsep}{0cm}%
41   \setlength{\fboxrule}{0.4pt}%
42   \setlength{\@showcubewidth}{#1}%
43   \advance\@showcubewidth by 1.6pt\relax%
44   \framebox{%
45     \begin{minipage}{\the\@showcubewidth}%
46     \centering%
47     \begin{tikzpicture}[scale=#2]%
48     #3%
49     \end{tikzpicture}%
50     \end{minipage}%
51   }}%
```

20.5 ShowSequence command

`\ShowSequence` The `\ShowSequence{<separator>}{<font-code>}{<sequence>}` command typesets a comma separated sequence of rotation commands. (See Section 11). This command takes three mandatory arguments: the first is the separator (**#1**), the second is the font or style code (**#2**), and third is a comma-separated sequence of Rubik rotation commands (**#3**).

This command requires the `forarray` package—by Christian Schröppel—for the `\ForEachX` command) and the `ifthen` package—by David Carlisle—for the `\ifthenelse` command). These two packages are loaded at startup if not already loaded. We first need to define two variables for use by the command; these are derived from the `forarray` package.

```
52 \newcommand{\x}{\thislevelitem}
53 \newcommand{\xcount}{\thislevelcount}
```

EXAMPLE USAGE: `\ForEachX{;}{\texttt{\x}}{L;R;U;D}`

An important feature of the `\ForEachX` command is that it expands its third argument (the list of elements), since this allows the list of elements to be presented as a macro, which is extremely convenient for the user.

The `\ShowSequence` command typesets a sequence of elements (`#3`), and places an optional separator (`#1`) between them. For each element (`\x`, see above) of the sequence `#3` this command forms the construction `#2{element of #3}`. For example, if `#2 = \rr`, and `D` is an element of `#3`, then it will form the command `\rr{D}` etc.

Note that it is not straightforward to place the separator (`#1`) *only between* the derived elements (i.e., without the separator being either before the first element, or following the last element) using only the `ForEachX` command. This is because the `ForEachX` command processes each element in exactly the same way—i.e., a comma after the first element (good) means there will be a comma after the final element (bad).

We solve this problem by using the `\ifthenelse` command to allow the first element to be processed differently from all the remaining elements. This is because it is easy for `TEX` to identify the first element of a sequence, but very difficult for it to identify the final element since we generally don't know the number of elements beforehand. Consequently we identify the first element (using the `\xcount` variable (see above), and then process this first element *without* any comma; we then place a comma in front of each of the remaining elements.

We also create two fbox versions of the command: the 'F' version places an fbox about the whole output; the 'f' version places an fbox about each element in the output (these two versions can be helpful when checking white space).

Note: bugfix 22 October 2017 (RWDN): if the user implemented tt output using `\tt` instead of the standard `\texttt` as the `#2` argument, then the action would not of course remain local, and consequently we have added a leading brace and complementary trailing brace around the the `\ifthenelse...` command in each of the following three macros to limit the action.

USAGE: `\ShowSequence{,}{\rr}{R,L,Up,Dp....}`

```

54 \newcommand{\ShowSequence}[3]{%
55   \ForEachX{,}{%
56     {\ifthenelse{\xcount=1}{#2{\x}}{#1#2{\x}}}%
57     }{#3}%
58 }%
59 \newcommand{\ShowSequenceF}[3]{%
60   \fbox{%
61     \ForEachX{,}{%
62       {\ifthenelse{\xcount=1}{#2{\x}}{#1#2{\x}}}%
63       }{#3}%
64 }}%
65 \newcommand{\ShowSequencef}[3]{%
66   \ForEachX{,}{%
67     {\ifthenelse{\xcount=1}{\fbox{#2{\x}}}{#1{\fbox{#2{\x}}}}}%
68     }{#3}%
69 }%
```

`\SequenceInfo` SEQUENCE HOLDERS: providing none of the Rubik rotation-codes has a trailing integer (e.g., R3) then the Rubik macros (`\rr`, `\rrh`, `\Rubik`, `\textRubik`) will work as expected when used as the second argument in the `\ShowSequence` command (described above). However, a problem arises when trying to process in this way any Rubik rotation-codes having a terminal integer (for example, short-codes e.g., R2, D3,...), since the `\ShowSequence` macro cannot expand short-codes into their long-code elements (e.g., R,R,D,D,D,...).

Accommodating such codes when using the `\ShowSequence` command is currently solved by using separate ‘holders’ for four derived strings, namely: `\SequenceInfo`, `\SequenceName`, `\SequenceShort` and `\SequenceLong` (for details see Section 11). These are generated automatically by the Perl RUBIKROTATION program, which returns a so-called ‘long’ version of the ‘short’ string (the argument of the `\RubikRotation` command). For example, the Perl program converts any short codes (e.g., R2, D3,...) → long form, e.g., R,R,D,D,D,... (see the RUBIKROTATION documentation for details). In order for the four ‘holders’ of these derived strings generated by the Perl program (written to the file `rubikstateNEW.dat`) to be accessible to the user they need to be defined here so that they can then be ‘redefined’ (by the Perl program) in the file `rubikstateNEW.dat`:

```
70 \newcommand{\SequenceInfo}{}{}% %% INFO only
71 \newcommand{\SequenceName}{}{}% %% NAME only
72 \newcommand{\SequenceShort}{}{}% %% original SHORT seq but with NO NAME
73 \newcommand{\SequenceLong}{}{}% %% just the LONG string & no name
```

20.6 SequenceBrace commands

`\SequenceBraceA` The `\SequenceBraceX{⟨name⟩}{⟨sequence⟩}` command is a tool for displaying a named sequence using a brace. The trailing A denotes that the brace is placed Above the sequence; B denotes the brace is Below the sequence. For usage see Section 12.

```
74 \newcommand{\SequenceBraceA}[2]{\overbrace{\mbox{#2}}^{\mbox{#1}}}%
75 \newcommand{\SequenceBraceB}[2]{\underbrace{\mbox{#2}}_{\mbox{#1}}}%
76 \newcommand{\SequenceBraceAF}[2]{\fbox{\overbrace{\mbox{#2}}^{\mbox{#1}}}}%
77 \newcommand{\SequenceBraceBF}[2]{\fbox{\underbrace{\mbox{#2}}_{\mbox{#1}}}}%
```

20.7 RubikFace commands

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

Cubie-facelet notation: t, m, b, l, m, r = top, middle, bottom, left, middle, right.

We use this lower case notation in XY-pairs to denote individual cubie facelets on a given face (to avoid confusion with cube Face notation), as follows:

top row (1,2,3) = lt, mt, rt
middle row (4,5,6) = lm, mm, rm
bottom row (7,8,9) = lb, mb, rb

For example, the current colour of the right bottom facelet on the FRONT face is held as the variable `\Frb` etc.

The cubie-facelets (squares) on a face are also parameterized numerically #1–#9 reading from left-to-right, starting top-left & ending bottom-right, when used as arguments for specifying particular colours (as in the `\RubikFace..` commands—see below).

`\RubikFaceUp` 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.

`\RubikFaceDown`

`\RubikFaceLeft` EXAMPLE: `\RubikFaceUp{R}{O}{Y} {G}{B}{W} {X}{R}{G}`

`\RubikFaceRight` Each of the 9 `\def{}` 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.

`\RubikFaceFront`

`\RubikFaceBack`

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

```

78 \newcommand{\RubikFaceUp}[9]{%
79 \def\Ult{#1}\def\Umt{#2}\def\Urt{#3}%
80 \def\Ulm{#4}\def\Umm{#5}\def\Urm{#6}%
81 \def\Ulb{#7}\def\Umb{#8}\def\Urb{#9}%
82 }
83 \newcommand{\RubikFaceFront}[9]{%
84 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
85 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
86 \def\Flb{#7}\def\Fmb{#8}\def\Frb{#9}%
87 }
88 \newcommand{\RubikFaceRight}[9]{%
89 \def\Rlt{#1}\def\Rmt{#2}\def\Rrt{#3}%
90 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
91 \def\Rlb{#7}\def\Rmb{#8}\def\Rrb{#9}%
92 }
93 \newcommand{\RubikFaceDown}[9]{%
94 \def\Dlt{#1}\def\Dmt{#2}\def\Drt{#3}%
95 \def\Dlm{#4}\def\Dmm{#5}\def\Drmm{#6}%
96 \def\Dlb{#7}\def\Dmb{#8}\def\Drb{#9}%
97 }
98 \newcommand{\RubikFaceLeft}[9]{%
99 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
100 \def\Llm{#4}\def\Lmm{#5}\def\Lrm{#6}%
101 \def\Llb{#7}\def\Lmb{#8}\def\Lrb{#9}%
102 }
103 \newcommand{\RubikFaceBack}[9]{%
104 \def\Blt{#1}\def\Bmt{#2}\def\Brt{#3}%
105 \def\Blm{#4}\def\Bmm{#5}\def\Brmm{#6}%
106 \def\Blb{#7}\def\Bmb{#8}\def\Brb{#9}%

```

107 }

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

```
108 \newcommand{\RubikFaceUpAll}[1]{%
109 \def\Ult{#1}\def\Umt{#1}\def\Urt{#1}%
110 \def\Ulm{#1}\def\Umm{#1}\def\Urm{#1}%
111 \def\Ulb{#1}\def\Umb{#1}\def\Urb{#1}%
112 }
113 \newcommand{\RubikFaceFrontAll}[1]{%
114 \def\Flt{#1}\def\Fmt{#1}\def\Frt{#1}%
115 \def\Flm{#1}\def\Fmm{#1}\def\Frm{#1}%
116 \def\Flb{#1}\def\Fmb{#1}\def\Frb{#1}%
117 }
118 \newcommand{\RubikFaceRightAll}[1]{%
119 \def\Rlt{#1}\def\Rmt{#1}\def\Rrt{#1}%
120 \def\Rlm{#1}\def\Rmm{#1}\def\Rrm{#1}%
121 \def\Rlb{#1}\def\Rmb{#1}\def\Rrb{#1}%
122 }
123 \newcommand{\RubikFaceLeftAll}[1]{%
124 \def\Llt{#1}\def\Lmt{#1}\def\Lrt{#1}%
125 \def\Llm{#1}\def\Lmm{#1}\def\Lrm{#1}%
126 \def\Llb{#1}\def\Lmb{#1}\def\Lrb{#1}%
127 }
128 \newcommand{\RubikFaceDownAll}[1]{%
129 \def\Dlt{#1}\def\Dmt{#1}\def\Drt{#1}%
130 \def\Dlm{#1}\def\Dmm{#1}\def\Drmm{#1}%
131 \def\DLb{#1}\def\DLmb{#1}\def\DLrb{#1}%
132 }
133 \newcommand{\RubikFaceBackAll}[1]{%
134 \def\Blt{#1}\def\Bmt{#1}\def\Brt{#1}%
135 \def\Blm{#1}\def\Bmm{#1}\def\Brmm{#1}%
136 \def\BLb{#1}\def\BLmb{#1}\def\BLrb{#1}%
137 }
```

Finally, we now use these commands to initialise all visible faces to the default colour grey (X)

```
138 \RubikFaceUpAll{X}%
139 \RubikFaceDownAll{X}%
140 \RubikFaceLeftAll{X}%
141 \RubikFaceRightAll{X}%
142 \RubikFaceFrontAll{X}%
143 \RubikFaceBackAll{X}%

```

20.8 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. The colour configuration of the central cubies matches those defined for the `RubikCubeSolved` command (i.e., white opposite yellow etc). We also make WY and WB versions, and implement equivalent ‘gray’ versions (to be consistent with TikZ).

```

144 \newcommand{\RubikCubeGrey}{%
145   \RubikFaceRight{X}{X}{X}{X}{G}{X}{X}{X}{X}%
146   \RubikFaceLeft {X}{X}{X}{X}{B}{X}{X}{X}{X}%
147   \RubikFaceUp    {X}{X}{X}{X}{W}{X}{X}{X}{X}%
148   \RubikFaceDown  {X}{X}{X}{X}{Y}{X}{X}{X}{X}%
149   \RubikFaceFront{X}{X}{X}{X}{O}{X}{X}{X}{X}%
150   \RubikFaceBack {X}{X}{X}{X}{R}{X}{X}{X}{X}%
151 }
152 \newcommand{\RubikCubeGray}{\RubikCubeGrey}
153 \newcommand{\RubikCubeGreyWY}{\RubikCubeGrey}
154 \newcommand{\RubikCubeGrayWY}{\RubikCubeGreyWY}
155 %%
156 \newcommand{\RubikCubeGreyWB}{%
157   \RubikFaceRight{X}{X}{X}{X}{R}{X}{X}{X}{X}%
158   \RubikFaceLeft {X}{X}{X}{X}{O}{X}{X}{X}{X}%
159   \RubikFaceUp    {X}{X}{X}{X}{W}{X}{X}{X}{X}%
160   \RubikFaceDown  {X}{X}{X}{X}{B}{X}{X}{X}{X}%
161   \RubikFaceFront{X}{X}{X}{X}{G}{X}{X}{X}{X}%
162   \RubikFaceBack {X}{X}{X}{X}{Y}{X}{X}{X}{X}%
163 }
164 \newcommand{\RubikCubeGrayWB}{\RubikCubeGreyWB}

```

20.9 SolvedConfig command

`\RubikSolvedConfig` This command sets the face/colour configuration (state) of a typical solved Rubik cube. Note that the order is Right, Left, Up, Down, Front, Back (i.e., X+, X−, Y+, Y−, Z+, Z−, order). We shall use this command to define solved cube configurations.

```

165 \newcommand{\RubikSolvedConfig}[6]{%
166   \RubikFaceRightAll{#1}%
167   \RubikFaceLeftAll{#2}%
168   \RubikFaceUpAll{#3}%
169   \RubikFaceDownAll{#4}%
170   \RubikFaceFrontAll{#5}%
171   \RubikFaceBackAll{#6}%
172 }

```

20.10 RubikCubeGreyAll command

`\RubikCubeGreyAll` This command sets the face/colour configuration (state) of a 3x3x3 Rubik cube with no colours allocated. This colour configuration is the same as the

startup default state—all cubies will appear grey. We implement it using the `\RubikSolvedConfig` command (above). We also implement an equivalent ‘gray’ version (to be consistent with TikZ).

```
173 \newcommand{\RubikCubeGreyAll}{\RubikSolvedConfig{X}{X}{X}{X}{X}{X}}%
174 \newcommand{\RubikCubeGrayAll}{\RubikCubeGreyAll}
```

20.11 RubikCubeSolved command

`\RubikCubeSolved` The first (default) command sets the face/colour configuration (state) one of the
`\RubikCubeSolvedWY` standard commercially available solved Rubik cube (white opposite yellow). The
`\RubikCubeSolvedWB` argument order follows the XYZ notation. For convenience we make a copy named
`\RubikCubeSolvedWY` (denoting the White opposite Yellow configuration), and
also a different version named `\RubikCubeSolvedWB` (denoting the White opposite
Blue configuration). These represent the two standard versions of the Rubik Cube.

```
175 \newcommand{\RubikCubeSolved}{\RubikSolvedConfig{G}{B}{W}{Y}{O}{R}}%
176 \newcommand{\RubikCubeSolvedWY}{\RubikCubeSolved}%
177 \newcommand{\RubikCubeSolvedWB}{\RubikSolvedConfig{R}{O}{W}{B}{G}{Y}}%
```

20.12 Slice commands

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

```
178 \newcommand{\RubikSliceTopR}[6]{%
179 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
180 \def\Rlt{#4}\def\Rmt{#5}\def\Rrt{#6}%
181 }
182 \newcommand{\RubikSliceTopL}[6]{%
183 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
184 \def\Flt{#4}\def\Fmt{#5}\def\Frt{#6}%
185 }
186 \newcommand{\RubikSliceMiddleR}[6]{%
187 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
188 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
189 }
190 \newcommand{\RubikSliceMiddleL}[6]{%
191 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
192 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
193 }
194 \newcommand{\RubikSliceEquatorR}[6]{%
195 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
196 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
197 }
198 \newcommand{\RubikSliceEquatorL}[6]{%
```

```

199 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
200 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
201 }
202 \newcommand{\RubikSliceBottomR}[6]{%
203 \def\Flb{#1}\def\Fmb{#2}\def\Frb{#3}%
204 \def\Rlb{#4}\def\Rmb{#5}\def\Rrb{#6}%
205 }
206 \newcommand{\RubikSliceBottomL}[6]{%
207 \def\Llb{#1}\def\Lmb{#2}\def\Lrb{#3}%
208 \def\Flb{#4}\def\Fmb{#5}\def\Frb{#6}%
209 }

```

20.13 Cube drawing macros

Since the three visible sides of a Rubik cube have up to 27 non-grey colours, and T_EX 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 viewing direction (X = either R or L; Y = either U or 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 → lt → rt → rb; the code being lb (LeftBottom), lt (LeftTop), rt (RightTop), rb (RightBottom) (only need four coords); the (x,y) 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).

```

210 \newcommand{\DrawRubikCubeFrontFace}{%
211 % ---top row left to right
212 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
213 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
214 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
215 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
216 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
217 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
218 % -----middle row left to right
219 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
220 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
221 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
222 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
223 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
224 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
225 % ----bottom row left to right

```

```

226 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
227 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
228 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
229 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
230 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
231 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
232 }

```

20.13.1 Viewing direction

The command ‘DrawRubikCubeXY’ command uses the trailing XY code to specify the view direction (X = either R or L; Y = either U or 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 (see Section 4). 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.

```

233 \newcommand{\DrawRubikCubeRU}{%
234 \DrawRubikCubeFrontFace %% frontface
235 %%-----Up face-----
236 %%---top row
237 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
238 (0.66,3.66) -- (1,4) -- (2,4) -- (1.66,3.66) -- cycle;
239 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
240 (1.66,3.66) -- (2,4) -- (3,4) -- (2.66,3.66) -- cycle;
241 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
242 (2.66,3.66) -- (3,4) -- (4,4) -- (3.66,3.66) -- cycle;
243 %%---middle row
244 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
245 (0.33,3.33) -- (0.66,3.66) -- (1.66,3.66) -- (1.33,3.33) -- cycle;
246 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
247 (1.33,3.33) -- (1.66,3.66) -- (2.66,3.66) -- (2.33,3.33) -- cycle;
248 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
249 (2.33,3.33) -- (2.66,3.66) -- (3.66,3.66) -- (3.33,3.33) -- cycle;
250 %%---bottom row
251 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
252 (0,3) -- (0.33,3.33) -- (1.33,3.33) -- (1,3) -- cycle;
253 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
254 (1,3) -- (1.33,3.33) -- (2.33,3.33) -- (2,3) -- cycle;
255 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%

```

```

256 (2,3) -- (2.33,3.33) -- (3.33,3.33) -- (3,3) -- cycle;
257 %%-----Right face-----
258 %%---top row
259 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
260 (3,2) -- (3, 3) -- (3.33,3.33) -- (3.33,2.33) -- cycle;
261 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
262 (3.33,2.33) -- (3.33, 3.33) -- (3.66,3.66) -- (3.66,2.66) -- cycle;
263 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
264 (3.66,2.66) -- (3.66, 3.66) -- (4,4) -- (4,3) -- cycle;
265 %%---middle row
266 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
267 (3,1) -- (3, 2) -- (3.33,2.33) -- (3.33,1.33) -- cycle;
268 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
269 (3.33,1.33) -- (3.33, 2.33) -- (3.66,2.66) -- (3.66,1.66) -- cycle;
270 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
271 (3.66,1.66) -- (3.66, 2.66) -- (4,3) -- (4,2) -- cycle;
272 %%---bottom row
273 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
274 (3,0) -- (3, 1) -- (3.33,1.33) -- (3.33,0.33) -- cycle;
275 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
276 (3.33,0.33) -- (3.33, 1.33) -- (3.66,1.66) -- (3.66,0.66) -- cycle;
277 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
278 (3.66,0.66) -- (3.66, 1.66) -- (4,2) -- (4,1) -- cycle;
279 }

```

`\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).

```
280 \newcommand{\DrawRubikCube}{\DrawRubikCubeRU}
```

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

```

281 \newcommand{\DrawRubikCubeRD}{%
282 \DrawRubikCubeFrontFace %% frontface
283 %%-----Right face-----
284 %%---top row
285 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
286 (3,2) -- (3, 3) -- (3.33,2.66) -- (3.33,1.66) -- cycle;
287 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
288 (3.33,1.66) -- (3.33, 2.66) -- (3.66,2.33) -- (3.66,1.33) -- cycle;
289 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
290 (3.66,1.33) -- (3.66, 2.33) -- (4,2) -- (4,1) -- cycle;
291 %%---middle row
292 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
293 (3,1) -- (3, 2) -- (3.33,1.66) -- (3.33,0.66) -- cycle;
294 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
295 (3.33,0.66) -- (3.33, 1.66) -- (3.66,1.33) -- (3.66,0.33) -- cycle;
296 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
297 (3.66,0.33) -- (3.66, 1.33) -- (4,1) -- (4,0) -- cycle;

```

```

298 %%---bottom row
299 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
300 (3,0) -- (3, 1) -- (3.33,0.66) -- (3.33,-0.33) -- cycle;
301 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
302 (3.33,-0.33) -- (3.33, 0.66) -- (3.66,0.33) -- (3.66,-0.66) -- cycle;
303 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
304 (3.66,-0.66) -- (3.66, 0.33) -- (4,0) -- (4,-1) -- cycle;
305 %%-----Down face-----
306 %%---top row
307 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
308 (0.33,-0.33) -- (0, 0) -- (1,0) -- (1.33,-0.33) -- cycle;
309 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
310 (1.33,-0.33) -- (1, 0) -- (2,0) -- (2.33,-0.33) -- cycle;
311 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
312 (2.33,-0.33) -- (2, 0) -- (3,0) -- (3.33,-0.33) -- cycle;
313 %%---middle row
314 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
315 (0.66,-0.66) -- (0.33, -0.33) -- (1.33,-0.33) -- (1.66,-0.66) -- cycle;
316 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
317 (1.66,-0.66) -- (1.33, -0.33) -- (2.33,-0.33) -- (2.66,-0.66) -- cycle;
318 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
319 (2.66,-0.66) -- (2.33, -0.33) -- (3.33,-0.33) -- (3.66,-0.66) -- cycle;
320 %%---bottom row
321 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
322 (1,-1) -- (0.66, -0.66) -- (1.66,-0.66) -- (2,-1) -- cycle;
323 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
324 (2,-1) -- (1.66, -0.66) -- (2.66,-0.66) -- (3,-1) -- cycle;
325 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
326 (3,-1) -- (2.66, -0.66) -- (3.66,-0.66) -- (4,-1) -- cycle;
327 }

```

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

```

328 \newcommand{\DrawRubikCubeLD}{%
329 \DrawRubikCubeFrontFace %% frontface
330 %%-----Left face-----
331 %%---top row
332 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
333 (-1,1) -- (-1, 2) -- (-0.66,2.33) -- (-0.66,1.33) -- cycle;
334 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
335 (-0.66,1.33) -- (-0.66, 2.33) -- (-0.33,2.66) -- (-0.33,1.66) -- cycle;
336 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
337 (-0.33,1.66) -- (-0.33, 2.66) -- (0,3) -- (0,2) -- cycle;
338 %%---middle row
339 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
340 (-1,0) -- (-1, 1) -- (-0.66,1.33) -- (-0.66,0.33) -- cycle;
341 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
342 (-0.66,0.33) -- (-0.66, 1.33) -- (-0.33,1.66) -- (-0.33,0.66) -- cycle;
343 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%

```

```

344 (-0.33,0.66) -- (-0.33, 1.66) -- (0,2) -- (0,1) -- cycle;
345 %%---bottom row
346 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
347 (-1,-1) -- (-1, 0) -- (-0.66,0.33) -- (-0.66,-0.66) -- cycle;
348 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
349 (-0.66,-0.66) -- (-0.66, 0.33) -- (-0.33,0.66) -- (-0.33,-0.33) -- cycle;
350 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
351 (-0.33,-0.33) -- (-0.33, 0.66) -- (0,1) -- (0,0) -- cycle;
352 %%-----Down face-----
353 %%---top row
354 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
355 (-0.33,-0.33) -- (0, 0) -- (1,0) -- (0.66,-0.33) -- cycle;
356 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
357 (0.66,-0.33) -- (1, 0) -- (2,0) -- (1.66,-0.33) -- cycle;
358 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
359 (1.66,-0.33) -- (2, 0) -- (3,0) -- (2.66,-0.33) -- cycle;
360 %%---middle row
361 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
362 (-0.66,-0.66) -- (-0.33, -0.33) -- (0.66,-0.33) -- (0.33,-0.66) -- cycle;
363 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
364 (0.33,-0.66) -- (0.66, -0.33) -- (1.66,-0.33) -- (1.33,-0.66) -- cycle;
365 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
366 (1.33,-0.66) -- (1.66, -0.33) -- (2.66,-0.33) -- (2.33,-0.66) -- cycle;
367 %%---bottom row
368 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
369 (-1,-1) -- (-0.66, -0.66) -- (0.33,-0.66) -- (0,-1) -- cycle;
370 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
371 (0,-1) -- (0.33, -0.66) -- (1.33,-0.66) -- (1,-1) -- cycle;
372 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
373 (1,-1) -- (1.33, -0.66) -- (2.33,-0.66) -- (2,-1) -- cycle;
374 }

```

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

```

375 \newcommand{\DrawRubikCubeLU}{%
376 \DrawRubikCubeFrontFace %% frontface
377 %%-----Left face-----
378 %%---top row
379 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
380 (-1,3) -- (-1, 4) -- (-0.66,3.66) -- (-0.66,2.66) -- cycle;
381 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
382 (-0.66,2.66) -- (-0.66, 3.66) -- (-0.33,3.33) -- (-0.33,2.33) -- cycle;
383 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
384 (-0.33,2.33) -- (-0.33, 3.33) -- (0,3) -- (0,2) -- cycle;
385 %%---middle row
386 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
387 (-1,2) -- (-1, 3) -- (-0.66,2.66) -- (-0.66,1.66) -- cycle;
388 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
389 (-0.66,1.66) -- (-0.66, 2.66) -- (-0.33,2.33) -- (-0.33,1.33) -- cycle;

```

```

390 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
391 (-0.33,1.33) -- (-0.33, 2.33) -- (0,2) -- (0,1) -- cycle;
392 %%---bottom row
393 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
394 (-1,1) -- (-1, 2) -- (-0.66,1.66) -- (-0.66,0.66) -- cycle;
395 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
396 (-0.66,0.66) -- (-0.66, 1.66) -- (-0.33,1.33) -- (-0.33,0.33) -- cycle;
397 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
398 (-0.33,0.33) -- (-0.33, 1.33) -- (0,1) -- (0,0) -- cycle;
399 %%-----Up face-----
400 %%---top row
401 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
402 (-0.66,3.66) -- (-1, 4) -- (0,4) -- (0.33,3.66) -- cycle;
403 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
404 (0.33,3.66) -- (0, 4) -- (1,4) -- (1.33,3.66) -- cycle;
405 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
406 (1.33,3.66) -- (1, 4) -- (2,4) -- (2.33,3.66) -- cycle;
407 %%---middle row
408 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
409 (-0.33,3.33) -- (-0.66, 3.66) -- (0.33,3.66) -- (0.66,3.33) -- cycle;
410 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
411 (0.66,3.33) -- (0.33, 3.66) -- (1.33,3.66) -- (1.66,3.33) -- cycle;
412 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
413 (1.66,3.33) -- (1.33, 3.66) -- (2.33,3.66) -- (2.66,3.33) -- cycle;
414 %%---bottom row
415 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
416 (0,3) -- (-0.33, 3.33) -- (0.66,3.33) -- (1,3) -- cycle;
417 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
418 (1,3) -- (0.66, 3.33) -- (1.66,3.33) -- (2,3) -- cycle;
419 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
420 (2,3) -- (1.66, 3.33) -- (2.66,3.33) -- (3,3) -- cycle;%
421 \ %%trailing space
422 }

```

RWDN19D removed DrawRubikLayerFace commands Feb 19 2018

20.14 DrawRubikFlatX commands

[BACKGROUND: These commands (new in version 3.0) were modified from the earlier `\FlatUp`, `\FlatDown` etc., commands; i.e., they were renamed as a set of `\Draw...` commands so as to make this notation consistent with the other `\Draw..` commands. Note also that the `\DrawRubikFace..` commands are essentially these same commands but with their two coordinate arguments X, Y set to $x = 0, y = 0$ —see Section 20.15]

<code>\DrawRubikFlatUp</code> <code>\DrawRubikFlatDown</code> <code>\DrawRubikFlatLeft</code> <code>\DrawRubikFlatRight</code> <code>\DrawRubikFlatFront</code> <code>\DrawRubikFlatBack</code>	<p>Each of these commands draws a separate (flat) face (9 facelets). Each command (except <code>\DrawRubikFlatFront</code>) 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 in relation to the cube itself.</p>
--	--

These commands were motivated by a need to be able to show hidden faces under certain circumstances.

Note also that the `\DrawRubikFlatFront` 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):

```
\DrawRubikFlatUp{0}{3}
```

These new commands are also used by the commands `\DrawRubikCubeF` and `\DrawRubikCubeSF` 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 a ‘dx, dy’ notation with the `\DrawRubikFlatDown` command (since dx and dy are already used by the `\cube@dx@dydz...` command), we encode these instead as (`\ddx`, `\ddy`).

```
423 \newcommand{\DrawRubikFlatUp}[2]{%
424 \pgfmathsetmacro{\ux}{#1}%
425 \pgfmathsetmacro{\uy}{#2}%
426 %%---top row
427 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
428 (\ux + 0,\uy + 2) -- (\ux + 0,\uy + 3) -- (\ux + 1,\uy + 3)%
429 -- (\ux + 1,\uy + 2) -- cycle;
430 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
431 (\ux + 1,\uy + 2) -- (\ux + 1,\uy + 3) -- (\ux + 2,\uy + 3)%
432 -- (\ux + 2,\uy + 2) -- cycle;
433 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
434 (\ux + 2,\uy + 2) -- (\ux + 2,\uy + 3) -- (\ux + 3,\uy + 3)%
435 -- (\ux + 3,\uy + 2) -- cycle;
436 %%----middle row
437 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
438 (\ux + 0,\uy + 1) -- (\ux + 0,\uy + 2) -- (\ux + 1,\uy + 2)%
439 -- (\ux + 1,\uy + 1) -- cycle;
440 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
441 (\ux + 1,\uy + 1) -- (\ux + 1,\uy + 2) -- (\ux + 2,\uy + 2)%
442 -- (\ux + 2,\uy + 1) -- cycle;
443 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
444 (\ux + 2,\uy + 1) -- (\ux + 2,\uy + 2) -- (\ux + 3,\uy + 2)%
445 -- (\ux + 3,\uy + 1) -- cycle;
446 %%----bottom row
447 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
448 (\ux + 0,\uy + 0) -- (\ux + 0,\uy + 1) -- (\ux + 1,\uy + 1)%
449 -- (\ux + 1,\uy + 0) -- cycle;
450 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
451 (\ux + 1,\uy + 0) -- (\ux + 1,\uy + 1) -- (\ux + 2,\uy + 1)%
452 -- (\ux + 2,\uy + 0) -- cycle;
453 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
454 (\ux + 2,\uy + 0) -- (\ux + 2,\uy + 1) -- (\ux + 3,\uy + 1)%
455 -- (\ux + 3,\uy + 0) -- cycle;
```



```

456 }
457 %%-----
458 \newcommand{\DrawRubikFlatDown}[2]{%
459 \pgfmathsetmacro{\ddx}{#1}%
460 \pgfmathsetmacro{\ddy}{#2}%
461 %%---top row
462 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
463 (\ddx + 0,\ddy + 2) -- (\ddx + 0,\ddy + 3) -- (\ddx + 1,\ddy + 3)%
464 -- (\ddx + 1,\ddy + 2) -- cycle;
465 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
466 (\ddx + 1,\ddy + 2) -- (\ddx + 1,\ddy + 3) -- (\ddx + 2,\ddy + 3)%
467 -- (\ddx + 2,\ddy + 2) -- cycle;
468 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
469 (\ddx + 2,\ddy + 2) -- (\ddx + 2,\ddy + 3) -- (\ddx + 3,\ddy + 3)%
470 -- (\ddx + 3,\ddy + 2) -- cycle;
471 %%----middle row
472 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
473 (\ddx + 0,\ddy + 1) -- (\ddx + 0,\ddy + 2) -- (\ddx + 1,\ddy + 2)%
474 -- (\ddx + 1,\ddy + 1) -- cycle;
475 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
476 (\ddx + 1,\ddy + 1) -- (\ddx + 1,\ddy + 2) -- (\ddx + 2,\ddy + 2)%
477 -- (\ddx + 2,\ddy + 1) -- cycle;
478 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
479 (\ddx + 2,\ddy + 1) -- (\ddx + 2,\ddy + 2) -- (\ddx + 3,\ddy + 2)%
480 -- (\ddx + 3,\ddy + 1) -- cycle;
481 %%----bottom row
482 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
483 (\ddx + 0,\ddy + 0) -- (\ddx + 0,\ddy + 1) -- (\ddx + 1,\ddy + 1)%
484 -- (\ddx + 1,\ddy + 0) -- cycle;
485 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
486 (\ddx + 1,\ddy + 0) -- (\ddx + 1,\ddy + 1) -- (\ddx + 2,\ddy + 1)%
487 -- (\ddx + 2,\ddy + 0) -- cycle;
488 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
489 (\ddx + 2,\ddy + 0) -- (\ddx + 2,\ddy + 1) -- (\ddx + 3,\ddy + 1)%
490 -- (\ddx + 3,\ddy + 0) -- cycle;
491 }
492 %%-----
493 \newcommand{\DrawRubikFlatLeft}[2]{%
494 \pgfmathsetmacro{\lx}{#1}%
495 \pgfmathsetmacro{\ly}{#2}%
496 %%---top row
497 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
498 (\lx + 0, \ly + 2) -- (\lx + 0, \ly + 3) -- (\lx + 1, \ly + 3)%
499 -- (\lx + 1, \ly + 2) -- cycle;
500 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
501 (\lx + 1, \ly + 2) -- (\lx + 1, \ly + 3) -- (\lx + 2, \ly + 3)%
502 -- (\lx + 2, \ly + 2) -- cycle;
503 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
504 (\lx + 2, \ly + 2) -- (\lx + 2, \ly + 3) -- (\lx + 3, \ly + 3)%
505 -- (\lx + 3, \ly + 2) -- cycle;

```

```

506 %%----middle row
507 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
508 (\lx + 0, \ly + 1) -- (\lx + 0, \ly + 2) -- (\lx + 1, \ly + 2)%
509 -- (\lx + 1, \ly + 1) -- cycle;
510 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
511 (\lx + 1, \ly + 1) -- (\lx + 1, \ly + 2) -- (\lx + 2, \ly + 2)%
512 -- (\lx + 2, \ly + 1) -- cycle;
513 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
514 (\lx + 2, \ly + 1) -- (\lx + 2, \ly + 2) -- (\lx + 3, \ly + 2)%
515 -- (\lx + 3, \ly + 1) -- cycle;
516 %%---bottom row
517 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
518 (\lx + 0, \ly + 0) -- (\lx + 0, \ly + 1) -- (\lx + 1, \ly + 1)%
519 -- (\lx + 1, \ly + 0) -- cycle;
520 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
521 (\lx + 1, \ly + 0) -- (\lx + 1, \ly + 1) -- (\lx + 2, \ly + 1)%
522 -- (\lx + 2, \ly + 0) -- cycle;
523 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
524 (\lx + 2, \ly + 0) -- (\lx + 2, \ly + 1) -- (\lx + 3, \ly + 1)%
525 -- (\lx + 3, \ly + 0) -- cycle;
526 }
527 %%-----
528 \newcommand{\DrawRubikFlatRight}[2]{%
529 \pgfmathsetmacro{\rx}{#1}%
530 \pgfmathsetmacro{\ry}{#2}%
531 %%---top row
532 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
533 (\rx + 0, \ry + 2) -- (\rx + 0, \ry + 3) -- (\rx + 1, \ry + 3)%
534 -- (\rx + 1, \ry + 2) -- cycle;
535 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
536 (\rx + 1, \ry + 2) -- (\rx + 1, \ry + 3) -- (\rx + 2, \ry + 3)%
537 -- (\rx + 2, \ry + 2) -- cycle;
538 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
539 (\rx + 2, \ry + 2) -- (\rx + 2, \ry + 3) -- (\rx + 3, \ry + 3)%
540 -- (\rx + 3, \ry + 2) -- cycle;
541 %%----middle row
542 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
543 (\rx + 0, \ry + 1) -- (\rx + 0, \ry + 2) -- (\rx + 1, \ry + 2)%
544 -- (\rx + 1, \ry + 1) -- cycle;
545 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
546 (\rx + 1, \ry + 1) -- (\rx + 1, \ry + 2) -- (\rx + 2, \ry + 2)%
547 -- (\rx + 2, \ry + 1) -- cycle;
548 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
549 (\rx + 2, \ry + 1) -- (\rx + 2, \ry + 2) -- (\rx + 3, \ry + 2)%
550 -- (\rx + 3, \ry + 1) -- cycle;
551 %%---bottom row
552 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
553 (\rx + 0, \ry + 0) -- (\rx + 0, \ry + 1) -- (\rx + 1, \ry + 1)%
554 -- (\rx + 1, \ry + 0) -- cycle;
555 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%

```

```

556 (\rx + 1, \ry + 0) -- (\rx + 1, \ry + 1) -- (\rx + 2, \ry + 1)%
557 -- (\rx + 2, \ry + 0) -- cycle;
558 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
559 (\rx + 2, \ry + 0) -- (\rx + 2, \ry + 1) -- (\rx + 3, \ry + 1)%
560 -- (\rx + 3, \ry + 0) -- cycle;
561 }
562 %%-----
563 \newcommand{\DrawRubikFlatFront}{%
564 %% This command is used /only/ by the \cmd{\DrawRubikCubeF} command.
565 %% NOTE: x, y variables not implemented as not required here
566 %%---top row
567 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
568 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
569 %%
570 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
571 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
572 %%
573 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
574 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
575 %%----middle row
576 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
577 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
578 %%
579 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
580 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
581 %%
582 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
583 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
584 %%---bottom row
585 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
586 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
587 %%
588 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
589 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
590 %%
591 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
592 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
593 }
594 %%-----
595 \newcommand{\DrawRubikFlatBack}[2]{%
596 \pgfmathsetmacro{\bx}{#1}%
597 \pgfmathsetmacro{\by}{#2}%
598 %%---top row
599 \draw[line join=round,line cap=round,ultra thick,fill=\Blt]%
600 (\bx + 0,\by + 2) -- (\bx + 0,\by + 3) -- (\bx + 1,\by + 3)%
601 -- (\bx + 1,\by + 2) -- cycle;
602 \draw[line join=round,line cap=round,ultra thick,fill=\Bmt]%
603 (\bx + 1,\by + 2) -- (\bx + 1,\by + 3) -- (\bx + 2,\by + 3)%
604 -- (\bx + 2,\by + 2) -- cycle;
605 \draw[line join=round,line cap=round,ultra thick,fill=\Brt]%

```

```

606 (\bx + 2,\by + 2) -- (\bx + 2,\by + 3) -- (\bx + 3,\by + 3)%
607 -- (\bx + 3,\by + 2) -- cycle;
608 %-----middle row
609 \draw[line join=round,line cap=round,ultra thick,fill=\Blm]%
610 (\bx + 0,\by + 1) -- (\bx + 0,\by + 2) -- (\bx + 1,\by + 2)%
611 -- (\bx + 1,\by + 1) -- cycle;
612 \draw[line join=round,line cap=round,ultra thick,fill=\Bmm]%
613 (\bx + 1,\by + 1) -- (\bx + 1,\by + 2) -- (\bx + 2,\by + 2)%
614 -- (\bx + 2,\by + 1) -- cycle;
615 \draw[line join=round,line cap=round,ultra thick,fill=\Brm]%
616 (\bx + 2,\by + 1) -- (\bx + 2,\by + 2) -- (\bx + 3,\by + 2)%
617 -- (\bx + 3,\by + 1) -- cycle;
618 %-----bottom row
619 \draw[line join=round,line cap=round,ultra thick,fill=\Blb]%
620 (\bx + 0,\by + 0) -- (\bx + 0,\by + 1) -- (\bx + 1,\by + 1)%
621 -- (\bx + 1,\by + 0) -- cycle;
622 \draw[line join=round,line cap=round,ultra thick,fill=\Bmb]%
623 (\bx + 1,\by + 0) -- (\bx + 1,\by + 1) -- (\bx + 2,\by + 1)%
624 -- (\bx + 2,\by + 0) -- cycle;
625 \draw[line join=round,line cap=round,ultra thick,fill=\Brb]%
626 (\bx + 2,\by + 0) -- (\bx + 2,\by + 1) -- (\bx + 3,\by + 1)%
627 -- (\bx + 3,\by + 0) -- cycle;
628 }

```

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

```

629 \newcommand{\DrawRubikCubeF}{%
630   \DrawRubikFlatUp{0}{3}%
631   \DrawRubikFlatDown{0}{-3}%
632   \DrawRubikFlatLeft{-3}{0}%
633   \DrawRubikFlatFront%
634   \DrawRubikFlatRight{3}{0}%
635   \DrawRubikFlatBack{6}{0}%
636 }

```

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

```

637 \newcommand{\DrawRubikCubeSF}{%
638   \DrawRubikCubeRU%
639   \DrawRubikFlatDown{0}{-3}%
640   \DrawRubikFlatLeft{-3}{0}%
641   \DrawRubikFlatBack{4}{1}%
642 }

```

20.14.1 DrawRubikFaceXSide commands

These six commands draw a face together with all four sidebars (colours only). They use the `\DrawRubikFlatX` commands to draw the face, and the `\side@bar..`

commands to draw the sidebars. Since each of the four sides of a face has three small (side) bars, we use a total of 12 `side@bar` commands for each command.

The parameter codes for the `\side@bar..` commands are as follows (see Section 20.16.1 for full details). Top (T) and Bottom (B) = left to right; Left (L) and Right (R) = top to bottom;

Note that since these commands are quite long, they all have a slightly more convenient short-hand version whereby the terminal two words are contracted to their two initial letters (see Section 20.15). RWDN19B

`\DrawRubikFaceUpSide` Draws the UP face together with all four sidebars.

```
643 \newcommand{\DrawRubikFaceUpSide}{%
644 \DrawRubikFlatUp{0}{0}%
645 %Top is a horizontal sidebar, so 1 = r, 3=1
646 \side@barT{1}{\Brt}
647 \side@barT{2}{\Bmt}
648 \side@barT{3}{\Blt}
649 %Left is a vertical sidebar, so 1 = r, 3=1
650 \side@barL{1}{\Lrt}
651 \side@barL{2}{\Lmt}
652 \side@barL{3}{\LLt}
653 %Right is a vertical sidebar, so 1 = l, 3=r
654 \side@barR{1}{\Rlt}
655 \side@barR{2}{\Rmt}
656 \side@barR{3}{\Rrt}
657 %Bottom is a horizontal sidebar, so 1 = l, 3=r
658 \side@barB{1}{\Flt}
659 \side@barB{2}{\Fmt}
660 \side@barB{3}{\Frt}
661 }
```

`\DrawRubikFaceFrontSide` Draws the FRONT face together with all four sidebars.

```
662 \newcommand{\DrawRubikFaceFrontSide}{%
663 \DrawRubikFlatFront{0}{0}%
664 %Top
665 \side@barT{1}{\Ulb}
666 \side@barT{2}{\Umb}
667 \side@barT{3}{\Urb}
668 %Left
669 \side@barL{1}{\Lrb}
670 \side@barL{2}{\Lrm}
671 \side@barL{3}{\Lrt}
672 %Right
673 \side@barR{1}{\Rlb}
674 \side@barR{2}{\Rlm}
675 \side@barR{3}{\Rlt}
676 %Bottom
677 \side@barB{1}{\Dlt}
678 \side@barB{2}{\Dmt}
679 \side@barB{3}{\Drt}
```

680 }

`\DrawRubikFaceRightSide` Draws the RIGHT face together with all four sidebars.

```
681 \newcommand{\DrawRubikFaceRightSide}{%
682 \DrawRubikFlatRight{0}{0}%
683 %Top
684 \side@barT{1}{\Urb}
685 \side@barT{2}{\Urm}
686 \side@barT{3}{\Urt}
687 %Left
688 \side@barL{1}{\Frb}
689 \side@barL{2}{\Frm}
690 \side@barL{3}{\Frt}
691 %Right
692 \side@barR{1}{\Blb}
693 \side@barR{2}{\Blm}
694 \side@barR{3}{\Blt}
695 %Bottom
696 \side@barB{1}{\Drt}
697 \side@barB{2}{\Drm}
698 \side@barB{3}{\Drb}
699 }
```

`\DrawRubikFaceLeftSide` Draws the LEFT face together with all four sidebars.

```
700 \newcommand{\DrawRubikFaceLeftSide}{%
701 \DrawRubikFlatLeft{0}{0}%
702 %Top
703 \side@barT{1}{\Ult}
704 \side@barT{2}{\Ulm}
705 \side@barT{3}{\Ulb}
706 %Left
707 \side@barL{1}{\Brb}
708 \side@barL{2}{\Brm}
709 \side@barL{3}{\Brt}
710 %Right
711 \side@barR{1}{\Flb}
712 \side@barR{2}{\Flm}
713 \side@barR{3}{\Flt}
714 %Bottom
715 \side@barB{1}{\Dlb}
716 \side@barB{2}{\Dlm}
717 \side@barB{3}{\Dlt}
718 }
```

`\DrawRubikFaceBackSide` Draws the BACK face together with all four sidebars.

```
719 \newcommand{\DrawRubikFaceBackSide}{%
720 \DrawRubikFlatBack{0}{0}%
721 %Top
722 \side@barT{1}{\Urt}
```

```

723 \side@barT{2}{\Umt}
724 \side@barT{3}{\Ult}
725 %Left
726 \side@barL{1}{\Rrb}
727 \side@barL{2}{\Rrm}
728 \side@barL{3}{\Rrt}
729 %Right
730 \side@barR{1}{\Llb}
731 \side@barR{2}{\Llm}
732 \side@barR{3}{\Llt}
733 %Bottom
734 \side@barB{1}{\Drb}
735 \side@barB{2}{\Dmb}
736 \side@barB{3}{\Dlb}
737 }

```

`\DrawRubikFaceDownSide` Draws the DOWN face together with all four sidebars.

```

738 \newcommand{\DrawRubikFaceDownSide}{%
739 \DrawRubikFlatDown{0}{0}%
740 %Top
741 \side@barT{1}{\Flb}
742 \side@barT{2}{\Fmb}
743 \side@barT{3}{\Frb}
744 %Left
745 \side@barL{1}{\Llb}
746 \side@barL{2}{\Lmb}
747 \side@barL{3}{\Lrb}
748 %Right
749 \side@barR{1}{\Rrb}
750 \side@barR{2}{\Rmb}
751 \side@barR{3}{\Rlb}
752 %Bottom
753 \side@barB{1}{\Brb}
754 \side@barB{2}{\Bmb}
755 \side@barB{3}{\Blb}
756 }

```

20.15 DrawRubikFace commands

BACKGROUND: The above `\DrawRubikFlat..` commands were originally just `\DrawFlat..` commands. They were subsequently copied & renamed (here) as the more intuitive `\DrawFace..` commands, since most of the time the user wants just to draw a particular face with or without sidebars.

In v5 it was necessary to rename them as `\DrawRubikFace...` commands since they relate to a 3x3x3 cube. At the same time we also included their more convenient short-hand versions (eg `\DrawRubikFaceUpSide` → `\DrawRubikFaceUS` etc), as the commands were getting a bit too long.

We therefore now deprecate the use of the earlier `\DrawFace...` commands,

although they will be maintained for the moment at least.

```

757 \newcommand{\DrawRubikFaceUp}{\DrawRubikFlatUp{0}{0}}
758 \newcommand{\DrawRubikFaceDown}{\DrawRubikFlatDown{0}{0}}
759 \newcommand{\DrawRubikFaceLeft}{\DrawRubikFlatLeft{0}{0}}
760 \newcommand{\DrawRubikFaceRight}{\DrawRubikFlatRight{0}{0}}
761 \newcommand{\DrawRubikFaceFront}{\DrawRubikFlatFront{0}{0}}
762 \newcommand{\DrawRubikFaceBack}{\DrawRubikFlatBack{0}{0}}

```

RWDN19A Finally, we create the short-hand versions.

```

763 \newcommand{\DrawRubikFaceU}{\DrawRubikFaceUp}
764 \newcommand{\DrawRubikFaceD}{\DrawRubikFaceDown}
765 \newcommand{\DrawRubikFaceL}{\DrawRubikFaceLeft}
766 \newcommand{\DrawRubikFaceR}{\DrawRubikFaceRight}
767 \newcommand{\DrawRubikFaceF}{\DrawRubikFaceFront}
768 \newcommand{\DrawRubikFaceB}{\DrawRubikFaceBack}
769 \newcommand{\DrawRubikFaceUS}{\DrawRubikFaceUpSide}
770 \newcommand{\DrawRubikFaceDS}{\DrawRubikFaceDownSide}
771 \newcommand{\DrawRubikFaceLS}{\DrawRubikFaceLeftSide}
772 \newcommand{\DrawRubikFaceRS}{\DrawRubikFaceRightSide}
773 \newcommand{\DrawRubikFaceFS}{\DrawRubikFaceFrontSide}
774 \newcommand{\DrawRubikFaceBS}{\DrawRubikFaceBackSide}

```

20.16 Sidebars (Face)

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 (see Section 10.6).

<code>\RubikSidebarWidth</code> <code>\RubikSidebarLength</code> <code>\RubikSidebarSep</code>	<p>These three commands allow the user to set the Width, Length and Separation parameters for the sidebar (in decimal values, where 1 is equivalent to the length of the side of a facelet).</p>
--	--

```

775 \newcommand{\RubikSidebarWidth}[1]{\pgfmathsetmacro{\bw}{#1}}
776 \newcommand{\RubikSidebarLength}[1]{\pgfmathsetmacro{\bl}{#1}}
777 \newcommand{\RubikSidebarSep}[1]{\pgfmathsetmacro{\bs}{#1}}

```

We first set some default values

```

778 \RubikSidebarWidth{0.3}%
779 \RubikSidebarLength{1}%
780 \RubikSidebarSep{0.3}%

```

In order to avoid conflicting nomenclature (between bar and Bar) we recommend using the lowercase ‘bar’ and deprecate the use of ‘Bar’ in commands. For backwards compatibility, however, we will retain the three original ‘Bar’ commands (for the moment at least), as follows:

```

781 \newcommand{\RubikSideBarWidth}[1]{\pgfmathsetmacro{\bw}{#1}}
782 \newcommand{\RubikSideBarLength}[1]{\pgfmathsetmacro{\bl}{#1}}
783 \newcommand{\RubikSideBarSep}[1]{\pgfmathsetmacro{\bs}{#1}}

```


20.16.1 Drawing and allocating a colour to a single facelet sidebar

Full length face sidebars are really multiple instances of small single facelet bars, each of which is drawn using one of the internal sidebar commands.

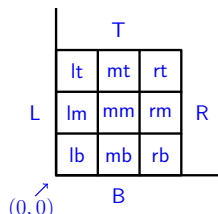


Figure 5: Face-edge and facelet-position codes (see text)

`\side@barT` There are four `\side@barX` commands, each with a trailing letter code `X`, which indicates the position of the sidebar relative to the square face displayed, namely `\side@barB` either T (Top), B (Bottom), L (Left) or R (Right) —see Figure 5.
`\side@barL`
`\side@barR` `\side@barL{<position-number>}{<facelet location-code>}`. Each `\side@barX` command takes two arguments: The first argument is a number (distance) `{<1 | 2 | 3>}` from the relevant axis depending on whether it is a vertical or horizontal sidebar (e.g., 1 = first bar (nearest the origin); 2 = second bar, 3 = third bar).

The second argument is the facelet location-code expressed as a command (e.g., `\Lrt`, `\Dlb` etc. Note that the facelet location uses a three letter code: the first (capital) letter (U, D, L, R, F, B) denotes the FACE; the second (lower-case) letter (l,m,r) is the ‘x’ position in the 3x3 matrix; the third (lower-case) letter (t,m,b) is the ‘y’ position —see Figure 5.

EXAMPLE: the following command draws a small single Right sidebar, in the middle position (no. 2), with the colour allocated to the Rlt facelet (left top facelet in the RIGHT face.

```
\side@barR{2}{\Rlt}
```

Notice that we use the command `\Rlt` as the argument; this is because the command is defined as: `\def{\Rlt}{#1}`, and hence the command gets replaced by the colour-code currently allocated to this particular facelet.

There are three small rectangular sidebars on each of the four sides of a 3x3 square face, and these are embedded in a coordinate system with origin at the bottom left corner (0,0) of the square face (see Figure 5).

The `\side@bar..` command also implements the set (or default) Rubik-SidebarLength `\bl`, RubikSidebarWidth `\bw` and RubikSidebarSep `\bs` (separation) values mentioned above. `\blh = Half \bl = \bl/2`. Note that the TikZ `\pgfmathsetmacro` commands (which do the maths) must be inside the `\side@bar..` command in order to work. The start point of the TikZ `\draw` command for each rectangular sidebar is the bottom Left corner of the sidebar = `(\dx,\dy)`.

`\no@sidebar` The `\NoSidebar{<colour code>}` command defines a (single) colour for which sidebars should *not* be drawn (particularly useful when drawing OLL configurations). This idea was suggested by Robert Mařík (May 2017) —see Section 10.8. The principle is that we let the command `\NoSidebar` define a face colour, and then we use the `\ifthenelse{equal{#2}{\no@sidebar}}{...}` structure inside the `\side@bar..` commands (see below) to either (a) draw all sidebars as usual (if `\NoSidebar` is undefined), or (b) draw all sidebars *except* those having the `\NoSidebar` colour (if `\NoSidebar` colour = #2).
 USAGE: `\NoSidebar{X}` If this command is *not* inside an environment, then its action will continue until it is disabled (undefined) as follows: `\NoSidebar{}`.

```

784 \def\no@sidebar{}%
785 \newcommand{\NoSidebar}[1]{\def\no@sidebar{#1}}

786 \newcommand{\side@barL}[2]{%
787   %% #1 = cubie possn no, #2 = colour
788   \ifthenelse{equal{#2}{\no@sidebar}}{}{%
789     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
790     \pgfmathsetmacro{\dx}{0 - \bs - \bw}%
791     \pgfmathsetmacro{\dy}{#1-1+0.5-\blh}%
792     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
793     -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
794   }}

795 \newcommand{\side@barR}[2]{%
796   %% #1 = cubie possn no, #2 = colour
797   \ifthenelse{equal{#2}{\no@sidebar}}{}{%
798     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
799     \pgfmathsetmacro{\dx}{3 + \bs}%
800     \pgfmathsetmacro{\dy}{#1 -1+0.5-\blh}%
801     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
802     -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
803   }}

804 \newcommand{\side@barT}[2]{%
805   %% #1 = cubie possn no, #2 = colour
806   \ifthenelse{equal{#2}{\no@sidebar}}{}{%
807     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
808     \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
809     \pgfmathsetmacro{\dy}{3 + \bs}%
810     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
811     -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
812   }}

813 \newcommand{\side@barB}[2]{%
814   %% #1 = cubie possn no, #2 = colour
815   \ifthenelse{equal{#2}{\no@sidebar}}{}{%
816     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
817     \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
818     \pgfmathsetmacro{\dy}{0 -\bs-\bw}%
819     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
820     -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
821   }}

```

RWDN19C removed 20:17:2 and 20:17:3 19 Feb 2018

20.17 Sidebars (Cube)

In order to position sidebars adjacent to a Rubik Cube (ie in 3D) requires that we first make some new `\side@bar..` commands for drawing sidebars adjacent to the BACK face of the cube (we have already made the macros for the front face sidebars—see Section 20.16). Furthermore, these new macros need to be tailored to each of the four standard cube viewing directions RU, LU, RD, LD.

Finally, the USER commands for drawing these sidebars need to accommodate (a) some code for identifying each set of sidebars, and (b) the viewing direction. So, for example, a USER command for drawing the sidebars associated with the cube edge formed by the RIGHT face and the BACK face (lets define this as the RB sidebar) as viewed from the RU direction, might be something like `\DrawRubikCubeSidebarRBRU`. Since this is not particularly user-friendly, we can improve on this slightly for the USER by (a) defining the sidebar as `SidebarRB`, and (b) appending the view direction in a curly bracket, say as `{RU}`. This allows a more intuitive command structure for the USER, as follows: `\DrawRubikCubeSidebarRB{RU}`. We then use the `\@join` command to append the string RU to the string `DrawRubicCubeSidebarRB` forming the (internal) command `\DrawRubicCubeSidebarRBRU`.

In the following we will group the code according to to the view direction (RU, LU, RD, LD).

20.17.1 Sidebars: RU view

Right-Back vert sidebar (RU view)

Need to write a new command for this position modified from `\side@barR` (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facelet bar

```

822 \newcommand{\side@barRubikRbackRU}[2]{%
823   %% #1 = cubie possn no, #2 = colour
824   %% dx --> dx+1
825   %% dy --> dy+1
826   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
827     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
828     \pgfmathsetmacro{\dx}{3 + \bs +1}%
829     \pgfmathsetmacro{\dy}{#1 -1+0.5-\blh +1}%
830     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
831     -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
832 }
```

Make the RB (RightBack) version; bar 1 is at the bottom

```

833 \newcommand{\DrawRubikCubeSidebarRBRU}{%
834 \side@barRubikRbackRU{3}{\Blt}%
835 \side@barRubikRbackRU{2}{\Blm}%
836 \side@barRubikRbackRU{1}{\Blb}%
```

837 }

Now do the reverse (BR) = RB

```
838 \newcommand{\DrawRubikCubeSidebarBRRU}{\DrawRubikCubeSidebarRBRU}
```

Make the join commands

```
839 \newcommand{\DrawRubikCubeSidebarRB}[1]{\@join{\DrawRubikCubeSidebarRB}{#1}}
```

```
840 \newcommand{\DrawRubikCubeSidebarBR}[1]{\@join{\DrawRubikCubeSidebarBR}{#1}}
```

Up-Back horiz sidebar (RU view)

Need to write a new command for this position modified from `\side@barT` (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facelet bar

```
841 \newcommand{\side@barRubikTbackRU}[2]{%
842   %% #1 = cubie possn no; #2 = colour
843   %% dx --> dx+1
844   %% dy --> dy+1
845   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
846     \pgfmithsetmacro{\blh}{\bl*(0.5)}%
847     \pgfmithsetmacro{\dx}{#1 -1+0.5-\blh +1}%
848     \pgfmithsetmacro{\dy}{3 +\bs +1}%
849     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
850     -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
851 }
```

Make the UB (Up-Back) version; bar 1 is at the left, 3 on the rhs (as we look at the image)

```
852 \newcommand{\DrawRubikCubeSidebarUBRU}{%
853 \side@barRubikTbackRU{1}{\BrT}%
854 \side@barRubikTbackRU{2}{\Bmt}%
855 \side@barRubikTbackRU{3}{\Blt}%
856 }
```

Now do the reverse (BU) = UB

```
857 \newcommand{\DrawRubikCubeSidebarBURU}{\DrawRubikCubeSidebarUBRU}
```

Make the join commands

```
858 \newcommand{\DrawRubikCubeSidebarUB}[1]{\@join{\DrawRubikCubeSidebarUB}{#1}}
```

```
859 \newcommand{\DrawRubikCubeSidebarBU}[1]{\@join{\DrawRubikCubeSidebarBU}{#1}}
```

Front-Left vert sidebar (RU view)

For the front face we can use the regular `\ide@barL` commands since it is the same as for an ordinary face sidebar

```
860 \newcommand{\DrawRubikCubeSidebarFLRU}{%
861 \side@barL{3}{\Lrt}%
862 \side@barL{2}{\Lrm}%
863 \side@barL{1}{\Lrb}%
864 }
```

Now do the reverse (LF)

```
865 \newcommand{\DrawRubikCubeSidebarLFRU}{\DrawRubikCubeSidebarFLRU}
```

Now do the two join commands

```
866 \newcommand{\DrawRubikCubeSidebarFL}[1]{\@join{\DrawRubikCubeSidebarFL}{#1}}
867 \newcommand{\DrawRubikCubeSidebarLF}[1]{\@join{\DrawRubikCubeSidebarLF}{#1}}
```

Front-Down horizontal sidebar (RU view)

Horiz sidebar, so 1 at the left, 2=middle, 3= rhs) here we have to use the B for bottom (of front face) and the facelets of the top row of the Down face

```
868 \newcommand{\DrawRubikCubeSidebarFDRU}{%
869 \side@barB{1}{\Dlt}%
870 \side@barB{2}{\Dmt}%
871 \side@barB{3}{\Drt}%
872 }
```

Now do the reverse (DF) = FD

```
873 \newcommand{\DrawRubikCubeSidebarDFRU}{\DrawRubikCubeSidebarFDRU}
```

Now do the two join commands

```
874 \newcommand{\DrawRubikCubeSidebarFD}[1]{\@join{\DrawRubikCubeSidebarFD}{#1}}
875 \newcommand{\DrawRubikCubeSidebarDF}[1]{\@join{\DrawRubikCubeSidebarDF}{#1}}
```

But FD-LU is the same as FD-RU, so need to make copies of each

```
876 \newcommand{\DrawRubikCubeSidebarDFLU}{\DrawRubikCubeSidebarFDRU}
877 \newcommand{\DrawRubikCubeSidebarFDLU}{\DrawRubikCubeSidebarFDRU}
```

20.17.2 Sidebars: LU view

Left-Back vert sidebar (LU view)

Need to write a new command for this position modified from \side@barL (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facelet bar

```
878 \newcommand{\side@barRubikLbackLU}[2]{%
879   %% #1 = cubie possn no, #2 = colour
880   %% dx --> dx-1
881   %% dy --> dy+1
882   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
883     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
884     \pgfmathsetmacro{\dx}{0 - \bs - \bw - 1}%
885     \pgfmathsetmacro{\dy}{#1 - 1 + 0.5 - \blh + 1}%
886     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
887     -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
888   }}
```

Make the LB (LeftBack) version; bar 1 is at the bottom

```
889 \newcommand{\DrawRubikCubeSidebarLBLU}{%
890 \side@barRubikLbackLU{3}{\Brb}%
891 \side@barRubikLbackLU{2}{\Brm}%
892 \side@barRubikLbackLU{1}{\Brb}%
893 }
```

Now do the reverse (BL) = LB

```
894 \newcommand{\DrawRubikCubeSidebarBLLU}{\DrawRubikCubeSidebarLBLU}
```

Make the join commands

```
895 \newcommand{\DrawRubikCubeSidebarLB}[1]{\@join{\DrawRubikCubeSidebarLB}{#1}}
896 \newcommand{\DrawRubikCubeSidebarBL}[1]{\@join{\DrawRubikCubeSidebarBL}{#1}}
```

Up-Back horizontal sidebar (LU view)

Modified from `\side@barT` (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facet bar

```
897 \newcommand{\side@barRubikTbackLU}[2]{%
898   %% #1 = cubie possn no; #2 = colour
899   %% dx --> dx-1
900   %% dy --> dy+1
901   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
902     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
903     \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh -1}%
904     \pgfmathsetmacro{\dy}{3 +\bs +1}%
905     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
906     -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
907 }
```

Make the UB (Up-Back) version; bar 1 is at the left, 3 on the rhs (as we look at the image)

```
908 \newcommand{\DrawRubikCubeSidebarUBLU}{%
909 \side@barRubikTbackLU{1}{\Brb}%
910 \side@barRubikTbackLU{2}{\Bmt}%
911 \side@barRubikTbackLU{3}{\Blt}%
912 }
```

Now do the reverse (BU) = UB

```
913 \newcommand{\DrawRubikCubeSidebarBULU}{\DrawRubikCubeSidebarUBLU}
```

Do not need to make the join commands as the USER commands for BU and UB are the same as for the RU.

Front-Right vertical sidebar (LU view)

Only needed for the LU view and LD. for the front face we can use the regular `side@barR` commands since it is the same as for an ordinary face sidebar RHS

```

914 \newcommand{\DrawRubikCubeSidebarFRLU}{%
915 \side@barR{3}{\Rlt}%
916 \side@barR{2}{\Rlm}%
917 \side@barR{1}{\Rlb}%
918 }

```

Now do the reverse (RF)

```

919 \newcommand{\DrawRubikCubeSidebarRFLU}{\DrawRubikCubeSidebarFRLU}

```

Now do the two join commands

```

920 \newcommand{\DrawRubikCubeSidebarFR}[1]{\@join{\DrawRubikCubeSidebarFR}{#1}}
921 \newcommand{\DrawRubikCubeSidebarRF}[1]{\@join{\DrawRubikCubeSidebarRF}{#1}}

```

20.17.3 Sidebars: RD view

Front-Up horizontal sidebar (RD view)

Horiz sidebar, so 1 at the left, 2=middle, 3= rhs here we have to use the T for bottom (of front face) and the facelets of the top row of the Down face

```

922 \newcommand{\DrawRubikCubeSidebarFURD}{%
923 \side@barT{1}{\Ulb}%
924 \side@barT{2}{\Umb}%
925 \side@barT{3}{\Urb}%
926 }

```

Now do the reverse (UF) = FU

```

927 \newcommand{\DrawRubikCubeSidebarUFRD}{\DrawRubikCubeSidebarFURD}

```

Now do the two join commands

```

928 \newcommand{\DrawRubikCubeSidebarFU}[1]{\@join{\DrawRubikCubeSidebarFU}{#1}}
929 \newcommand{\DrawRubikCubeSidebarUF}[1]{\@join{\DrawRubikCubeSidebarUF}{#1}}

```

Front-Left vertical sidebar (RD view)

Front LEFT (RD view = same as for RU)

```

930 \newcommand{\DrawRubikCubeSidebarFLRD}{\DrawRubikCubeSidebarFLRU}
931 \newcommand{\DrawRubikCubeSidebarLFRD}{\DrawRubikCubeSidebarLFRU}

```

Right-Back vertical sidebar (RD view)

Modified from \side@barR (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facelet bar

```

932 \newcommand{\side@barRubikRbackRD}[2]{%
933   %% #1 = cubie possn no, #2 = colour
934   %% dx --> dx+1
935   %% dy --> dy-1
936   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%

```

```

937 \pgfmithsetmacro{\blh}{\bl*(0.5)}%
938 \pgfmithsetmacro{\dx}{3 + \bs +1}%
939 \pgfmithsetmacro{\dy}{#1 -1+0.5-\blh -1}%
940 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
941 -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
942 }

```

Make the RB (RightBack) version; bar 1 is at the bottom

```

943 \newcommand{\DrawRubikCubeSidebarRRD}{%
944 \side@barRubikRbackRD{3}{\Blt}%
945 \side@barRubikRbackRD{2}{\Blm}%
946 \side@barRubikRbackRD{1}{\Blb}%
947 }

```

Now do the reverse (BR) = RB

```

948 \newcommand{\DrawRubikCubeSidebarRRD}{\DrawRubikCubeSidebarRRD}

```

Do NOT need to make the join commands (same as for the RU view)

Down-Back horizotal sidebar (RD view)

Modified from \side@barB (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facelet bar

```

949 \newcommand{\side@barRubikBbackRD}[2]{%
950 %% #1 = cubie possn no; #2 = colour
951 %% dx --> dx+1
952 %% dy --> dy-1
953 \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
954 \pgfmithsetmacro{\blh}{\bl*(0.5)}%
955 \pgfmithsetmacro{\dx}{#1 -1+0.5-\blh +1}%
956 \pgfmithsetmacro{\dy}{0 -\bs - \bw -1}%
957 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
958 -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
959 }

```

Make the DB (Down-Back) version; bar 1 is at the left, 3 on the rhs (as we look at the image)

```

960 \newcommand{\DrawRubikCubeSidebarDBRD}{%
961 \side@barRubikBbackRD{1}{\Brb}%
962 \side@barRubikBbackRD{2}{\Bmb}%
963 \side@barRubikBbackRD{3}{\Blb}%
964 }

```

Now do the reverse (BD) = DB

```

965 \newcommand{\DrawRubikCubeSidebarBDRD}{\DrawRubikCubeSidebarDBRD}

```

Make the join commands

```

966 \newcommand{\DrawRubikCubeSidebarDB}[1]{\@join{\DrawRubikCubeSidebarDB}{#1}}
967 \newcommand{\DrawRubikCubeSidebarBD}[1]{\@join{\DrawRubikCubeSidebarBD}{#1}}

```


20.17.4 Sidebars: LD view

Front-Up horizontal sidebar (LD view)

But FR (LD view) is the same as for (RU view), (see above)

```
968 \newcommand{\DrawRubikCubeSidebarFULD}{\DrawRubikCubeSidebarFURD}
969 \newcommand{\DrawRubikCubeSidebarUFLD}{\DrawRubikCubeSidebarUFRD}
```

Front-Right vertical sidebar (LD view)

Front Right (LDview) = same as for (LU view), (see above)

```
970 \newcommand{\DrawRubikCubeSidebarFRLD}{\DrawRubikCubeSidebarFRLU}
971 \newcommand{\DrawRubikCubeSidebarRFLD}{\DrawRubikCubeSidebarRFLU}
```

Left-Back vertical sidebar (LD view)

Modified from `\side@barL` (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facet bar

```
972 \newcommand{\side@barRubikLbackLD}[2]{%
973   %% #1 = cubie possn no, #2 = colour
974   %% dx --> dx-1
975   %% dy --> dy-1
976   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
977     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
978     \pgfmathsetmacro{\dx}{0 - \bs -\bw -1}%
979     \pgfmathsetmacro{\dy}{#1 -1+0.5-\blh -1}%
980     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
981     -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
982 }
```

Make the LB (LeftBack) version; bar 1 is at the bottom

```
983 \newcommand{\DrawRubikCubeSidebarLBLD}{%
984 \side@barRubikLbackLD{3}{\BrT}%
985 \side@barRubikLbackLD{2}{\BrM}%
986 \side@barRubikLbackLD{1}{\BrB}%
987 }
```

Now do the reverse (BL) = LB

```
988 \newcommand{\DrawRubikCubeSidebarBLLD}{\DrawRubikCubeSidebarLBLD}
```

Do NOT need to make the join commands (same as for the LU view)

Down-Back horizontal sidebar (LD view)

Modified from `\side@barB` (in Section 20.16.1) draws only a single small bar each of the three small bars has a numbered position (1,2,3); (dx,dy) = bottom Left corner of single facet bar

```

989 \newcommand{\side@barRubikBbackLD}[2]{%
990   %% #1 = cubie possn no; #2 = colour
991   %% dx --> dx-1
992   %% dy --> dy-1
993   \ifthenelse{\equal{#2}{\no@sidebar}}{}{%
994     \pgfmathsetmacro{\blh}{\bl*(0.5)}%
995     \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh -1}%
996     \pgfmathsetmacro{\dy}{0 -\bs - \bw -1}%
997     \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
998     -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
999 }

```

Make the DB (Down-Back) version; bar 1 is at the left, 3 on the rhs (as we look at the image)

```

1000 \newcommand{\DrawRubikCubeSidebarDBLD}{%
1001 \side@barRubikBbackLD{1}{\Brb}%
1002 \side@barRubikBbackLD{2}{\Bmb}%
1003 \side@barRubikBbackLD{3}{\Blb}%
1004 }

```

Now do the reverse (BD) = DB

```

1005 \newcommand{\DrawRubikCubeSidebarBDLD}{\DrawRubikCubeSidebarDBLD}

```

Do NOT need to make the join commands (same as for the RD view)

20.18 DrawNCube 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 = colours 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.

```

1006 \newcommand{\DrawNCubeAll}[4]{%
1007   \pgfmathsetmacro{\ncubes}{#1-1}%
1008   %% need to subtract 1 from the given number of cubies per side
1009   %% to avoid the origin of the initial cube to be displaced
1010   \foreach \x in {0,...,\ncubes}{%

```

```

1011      \foreach \y in {0,...,\ncubes}{%
1012          \foreach \z in {0,...,\ncubes}{%
1013              \cube@dx dy dz{1}{#2}{#3}{#4}{\x}{\y}{\z}%
1014      }}}

```

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

```

1015 \newcommand{\cube@dx dy dz}[7]{%
1016     \pgfmathsetmacro{\dx}{#1+#5}%
1017     %% calculates the 'displacement' (distance from the origin) of the
1018     %% far corners of the cube along the x axis from the arguments
1019     \pgfmathsetmacro{\dy}{#1+#6}%
1020     %% calculates the 'displacement' (distance from the origin) of the
1021     %% far corners of the cube along the y axis from the arguments
1022     \pgfmathsetmacro{\dz}{#1+#7}%
1023     %% calculates the 'displacement' (distance from the origin) of the
1024     %% far corners of the cube along the z axis from the arguments
1025     %% Draw FRONT face (using the X colour = #4)
1026     \draw[line join=round,line cap=round,ultra thick,fill=#4]%
1027     (#5,#6,\dz) -- (\dx,#6,\dz) -- (\dx,\dy,\dz) -- (#5,\dy,\dz) -- cycle;
1028     %% The 'rectangle' command does not work with 3D coordinates,
1029     %% so this is the way to draw the squares with space coordinates
1030     %% Draw UP face (using the Y colour = #3)
1031     \draw[line join=round,line cap=round,ultra thick,fill=#3]%
1032     (#5,\dy,\dz) -- (\dx,\dy,\dz) -- (\dx,\dy,#7) -- (#5,\dy,#7) -- cycle;

```

```

1033 %% Draw RIGHT face    (using the X colour = #2)
1034 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
1035 (\dx,#6,\dz) -- (\dx,#6,#7) -- (\dx,\dy,#7) -- (\dx,\dy,\dz) -- cycle;
1036 }

```

20.19 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 the variables here since these names
have been allocated already (see above). However, we can use `dx`, `dy` in the
command names as these will be more readily understood by the user.

```

1037 \newcommand{\Cubiedx}[1]{\pgfmathsetmacro{cx}{#1}}
1038 \newcommand{\Cubiedy}[1]{\pgfmathsetmacro{cy}{#1}}

```

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

```

1039 \Cubiedx{0.4}
1040 \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}`

```

1041 \newcommand{\DrawCubieRU}[3]{%
1042 %% Front face (z)
1043 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
1044 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
1045 %% Up face(y)
1046 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
1047 (0,1) -- (\cx, 1+\cy) -- (1+\cx,1+\cy) -- (1,1) -- cycle;
1048 %% Right face(x)
1049 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
1050 (1,0) -- (1,1) -- (1+\cx,1+\cy) -- (1+\cx, \cy) -- cycle;
1051 }
1052 \newcommand{\DrawCubieRD}[3]{%
1053 %% Front face (z)
1054 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
1055 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
1056 %% Down face (y)
1057 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
1058 (\cx,-\cy) -- (0, 0) -- (1,0) -- (1+\cx,-\cy) -- cycle;
1059 %% Right face (x)
1060 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
1061 (1,0) -- (1,1) -- (1+\cx,-\cy+1) -- (1+\cx, -\cy) -- cycle;
1062 }

```

```

1063 \newcommand{\DrawCubieLD}[3]{%
1064 %% Front face (z)
1065 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
1066 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
1067 %% Down face (y)
1068 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
1069 (-\cx,-\cy) -- (0, 0) -- (1,0) -- (1-\cx,-\cy) -- cycle;
1070 %% Left face (x)
1071 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
1072 (-\cx,-\cy) -- (-\cx,-\cy+1) -- (0,1) -- (0,0) -- cycle;
1073 }
1074 \newcommand{\DrawCubieLU}[3]{%
1075 %% Front face (z)
1076 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
1077 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
1078 %% Up face (y)
1079 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
1080 (-\cx,1+\cy) -- (1-\cx, 1+\cy) -- (1,1) -- (0,1) -- cycle;
1081 %% Left face (x)
1082 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
1083 (-\cx, \cy) -- (-\cx,\cy+1) -- (0,1) -- (0,0) -- cycle;
1084 }

```

20.20 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 (since just three faces are visible with this cube format), 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}`

```

1085 \newcommand{\textCubieRU}[3]{%
1086 \begin{minipage}{0.66cm}
1087 \centering
1088 \begin{tikzpicture}[scale=0.5]
1089 \Cubiedx{0.4}\Cubiedy{0.4}
1090 \DrawCubieRU{#1}{#2}{#3}
1091 \end{tikzpicture}%
1092 \end{minipage}
1093 }
1094 \newcommand{\textCubieRD}[3]{%
1095 \begin{minipage}{0.66cm}
1096 \centering
1097 \begin{tikzpicture}[scale=0.5]

```

```

1098 \Cubiedx{0.4}\Cubiedy{0.4}
1099 \DrawCubieRD{#1}{#2}{#3}
1100 \end{tikzpicture}%
1101 \end{minipage}
1102 }
1103 \newcommand{\textCubieLD}[3]{%
1104 \begin{minipage}{0.66cm}
1105 \centering
1106 \begin{tikzpicture}[scale=0.5]
1107 \Cubiedx{0.4}\Cubiedy{0.4}
1108 \DrawCubieLD{#1}{#2}{#3}
1109 \end{tikzpicture}%
1110 \end{minipage}
1111 }
1112 \newcommand{\textCubieLU}[3]{%
1113 \begin{minipage}{0.66cm}
1114 \centering
1115 \begin{tikzpicture}[scale=0.5]
1116 \Cubiedx{0.4}\Cubiedy{0.4}
1117 \DrawCubieLU{#1}{#2}{#3}
1118 \end{tikzpicture}%
1119 \end{minipage}
1120 }

```

20.21 Rotation commands

20.21.1 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 Rubik 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.

In version 3.0, however, all the rotation commands were also made available to the user in the much more intuitive form `stem{argument}` form, for example, `\rrh{D}`. In practice, this ‘argument’ form actually generates the original non-argument form by the use of the internal macro `\@join`. For example, `\rrh{D}` \rightarrow `join(\rrh + D) \rightarrow \rrhD` (see Section 20.21.4 for details).

The hieroglyphs are of two types: ‘arrow’ glyphs (all exactly square), and ‘letter’ glyphs (mostly square, but many are rectangular); however both types are designed to have the same height so they sit nicely when arranged side-by-side. A lot of special macros for generating these glyphs are described below in Section 20.21.3 (and also in Section 20.21.2).

The ‘arrow’ hieroglyphs are built up in stages using TikZ. We first create a command for drawing the square (`\DrawNotationBox`; see Section 20.21.2) and

then draw the contents (lines, arrows, arcs of circles). For an example, see the D form  constructed in Section 20.21.13.

The ‘letter’ hieroglyphs (glyphs for which the rotations cannot be seen from the front, and hence cannot have arrows) just give a letter representation of the rotation (say, Bw for ‘back wide’). These glyphs are therefore made using an fbox (for convenience), and therefore these are sometimes not square. Some vertical fine-tuning using the `\raisebox` command is often required to force these ‘letter’ glyphs to have the same vertical position as their ‘arrow’ cousins. A typical example is the form  which is detailed in Section 20.21.7.

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

20.21.2 DrawNotationBox

`\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.

```
1121 \newcommand{\DrawNotationBox}{%
1122   \draw [thick] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0) -- (0,1)%
1123 }
```

We now define a number of points and line-segments inside the square ‘notationbox’ (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 centre and a start point. Note that the final argument does not use any units. For the TikZ ARC command see TikZ pgfmanual (2012) page 146 (§14.8).

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

```
1124 \pgfmathsetmacro{\@sd}{0.25} % a small horiz space
1125 \pgfmathsetmacro{\@sdd}{2*\@sd} % 2x horiz space
1126 \pgfmathsetmacro{\@sddd}{3*\@sd} % 3x horiz space
1127 \pgfmathsetmacro{\@sh}{0.6} % height
1128 \pgfmathsetmacro{\@sb}{0.2} % base
1129 \pgfmathsetmacro{\@sbh}{\@sb + \@sh} % UP
1130 \pgfmathsetmacro{\@scx}{\@sdd+0.2} % Start of CircleX arc
1131 \pgfmathsetmacro{\@scy}{\@sd*2/3} % Start of CircleY arc
1132 \pgfmathsetmacro{\@scx}{\@scx-0.13} %% Square CenterX coord
1133 \pgfmathsetmacro{\@scy}{\@scy+0.25} %% Square CenterY cprdr
```

20.21.3 Some useful internal commands

`\@rr` These internal commands are used to generate the prime, w, w-prime, s, s-prime,
`\@rrp` a, a-prime rotation commands. They attach a letter or a prime to the associated
`\@rrw`
`\@rrwp`
`\@rrs`
`\@rrsp`
`\@rra`
`\@rrap`
`\@xyzh`
`\@xyzhp`
`\@xyzRubik`
`\@xyzRubikp`
`\@SquareLetter`

argument; for example, the command `\@rrwp{B}` appends a ‘w’ and a prime (p) to the argument ‘B’, i.e. $\rightarrow \mathbf{Bw}'$ (see Section 20.21.8). Users are then able to access this glyph by typing the command `\rrBwp`, or, more intuitively, `\rr{Bwp}` (see also `\@join` detailed in Section 20.21.4).

The `\@xyz..` commands are used to generate the x, y, z, u, d, l, r, f, b commands and their associated prime rotation commands. The commands `\@xyzhbdfl` and `\@xyzbdfRubik` relate to the axis rotations denoted as b, d, f, l; since these four letters have long upstrokes they require special fine-tuning for vertical position.

The `\@SquareLetter` command is used to form the separate square hieroglyph form used for rotations with no visible representation from the front (e.g., B., Fs, Fsp, Fa, Fap, S, Sp, Sf, Sfp, Sb, Sbp). Note that the TikZ ‘thick’ line code = 0.8pt (used in `\@SquareLetter`). 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 taking parameters we are able to more easily standardise the size and position of all the various glyphs. For details of the rubikfont and rubikprime see Section 20.3).

```

1134 \newcommand{\@rr}[1]{\@rubikfont #1}
1135 \newcommand{\@rrp}[1]{\@rubikfont #1\@rubikprime}
1136 \newcommand{\@rrw}[1]{\@rubikfont #1\@rubikfontFNS w}}
1137 \newcommand{\@rrwp}[1]{\@rubikfont #1\@rubikfontFNS w}\@rubikprime}
1138 \newcommand{\@rrs}[1]{\@rubikfont #1\@rubikfontFNS s}}
1139 \newcommand{\@rrsp}[1]{\@rubikfont #1\@rubikfontFNS s}\@rubikprime}
1140 \newcommand{\@rra}[1]{\@rubikfont #1\@rubikfontFNS a}}
1141 \newcommand{\@rrap}[1]{\@rubikfont #1\@rubikfontFNS a}\@rubikprime}
1142 \newcommand{\@rru}[1]{\@rubikfont #1\@rubikfontFNS u}}
1143 \newcommand{\@rrup}[1]{\@rubikfont #1\@rubikfontFNS u}\@rubikprime}
1144 \newcommand{\@rrd}[1]{\@rubikfont #1\@rubikfontFNS d}}
1145 \newcommand{\@rrdp}[1]{\@rubikfont #1\@rubikfontFNS d}\@rubikprime}
1146 \newcommand{\@rrl}[1]{\@rubikfont #1\@rubikfontFNS l}}
1147 \newcommand{\@rrlp}[1]{\@rubikfont #1\@rubikfontFNS l}\@rubikprime}
1148 \newcommand{\@rrr}[1]{\@rubikfont #1\@rubikfontFNS r}}
1149 \newcommand{\@rrrp}[1]{\@rubikfont #1\@rubikfontFNS r}\@rubikprime}
1150 \newcommand{\@rrf}[1]{\@rubikfont #1\@rubikfontFNS f}}
1151 \newcommand{\@rrfp}[1]{\@rubikfont #1\@rubikfontFNS f}\@rubikprime}
1152 \newcommand{\@rrb}[1]{\@rubikfont #1\@rubikfontFNS b}}
1153 \newcommand{\@rrbp}[1]{\@rubikfont #1\@rubikfontFNS b}\@rubikprime}
1154 \newcommand{\@rrc}[1]{\@rubikfont #1\@rubikfontFNS c}}
1155 \newcommand{\@rrcp}[1]{\@rubikfont #1\@rubikfontFNS c}\@rubikprime}
1156 \newcommand{\@rrm}[1]{\@rubikfont #1\@rubikfontFNS m}}
1157 \newcommand{\@rrmp}[1]{\@rubikfont #1\@rubikfontFNS m}\@rubikprime}
1158 \newcommand{\@xyzh}[1]{\@rubikfont #1}}
1159 \newcommand{\@xyzhp}[1]{\@rubikfont #1\raisebox{-0.6pt}{\@rubikprime}}}
1160 \newcommand{\@xyzRubik}[1]{%
1161   {\raisebox{3.45pt}{\@rubikfont #1}}}
1162 \newcommand{\@xyzRubikp}[1]{%
1163   {\raisebox{3.45pt}{\@rubikfont #1\raisebox{-0.6pt}{\@rubikprime}}}}

```



```

1164 \newcommand{\@xyzhbdfl}[1]%
1165   {[\raisebox{-0.6pt}{\@rubikfont #1}]}
1166 \newcommand{\@xyzhbdfllp}[1]%
1167   {[\raisebox{-0.6pt}{\@rubikfont #1\@rubikprime}]}
1168 \newcommand{\@xyzbdfllRubik}[1]%
1169   {[\raisebox{3.45pt}{[\raisebox{-0.6pt}{\@rubikfont #1}]}]}
1170 \newcommand{\@xyzbdfllRubikp}[1]%
1171   {[\raisebox{3.45pt}{[\raisebox{-0.6pt}{\@rubikfont #1\@rubikprime}]}]}
1172 \newcommand{\@SquareLetter}[1]{\setlength{\fboxsep}{2.5pt}%
1173   \setlength{\fboxrule}{0.8pt}%
1174   \fbox{\rule[-1pt]{0pt}{8.5pt}\raisebox{-0.5pt}{#1}}}
1175 \newlength\@hRubik%
1176 \setlength{\@hRubik}{0.185cm}%

```

`\@tlen` Feb 2017 (RWDN): We also need to define a small length for fine-tuning the default horizontal space between a pair of ‘letter’ hieroglyphs, eg B (i.e., when no additional space has been added by the user), so that this matches that between a pair of ‘arrow’ hieroglyphs. This length is inserted on both sides of the square frame. This length is used in two settings: (a) in ‘letter’ hieroglyphs (for an example, see the definition of the macro `\SquareB` in Section 20.21.5), and in (b) in ‘arrow’ hieroglyphs (for an example, see the definition of the macro `\rrhD` in Section 20.21.13).

```

1177 \newcommand{\@tlen}{\hspace{1pt}}%

```

20.21.4 Using `\@join`

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

USAGE: `\@join{<command-stem>}{<rotation-code>}`. For example, to create the command `\rrhU` we would write `\@join{\rrh}{U}`, and hence the intuitive command `\rrhU` is equivalent to `\rrhU`.

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.

```

1178 \newcommand*\@join[2]{%
1179   \csname\expandafter\@gobble\string#1#2\endcsname}

```

The following section shows how this command is used in practice.

`\textRubik` The following four commands typeset a single rotation, where a rotation-code
`\Rubik` (e.g., U) is the argument (see Section 9.1). As an example, the format for the
`\rr` `\rrh{}` command is `\rrh{<rotation-code>}`. In practice, these four commands are
`\rrh` really a sort of front-end for all the commands which follow this section. For ex-
 ample, the command `\rrhU` 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 above), are especially useful when typesetting a list of rotation-codes. Furthermore, it is

more intuitive for the user to specify a rotation command using the rotation-code as an argument.

```
1180 \newcommand*{\Rubik}[1]{\@join{\Rubik}{#1}}
1181 \newcommand*{\textRubik}[1]{\@join{\textRubik}{#1}}
1182 \newcommand*{\rr}[1]{\@join{\rr}{#1}}
1183 \newcommand*{\rrh}[1]{\@join{\rrh}{#1}}
```

20.21.5 Rotation B

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

`\SquareB`

`\rrhB` Feb 2017 (RWDN): added the `\@tlen` length (= 1pt; defined above) to the

`\RubikB` `\SquareB` command, and removed the terminal `\`, space from the `rrhB`, `RubikB`,

`\textRubikB` `textRubikB` commands, and copied this action with all the subsequent Letter hieroglyphs (e.g., `B`, `Bw`,...). These minor changes were to improve the spacing between two Letter hieroglyphs, and make it match that between two square ‘arrow’ hieroglyphs. The same changes were made to all the ‘letter’ hieroglyphs.

```
1184 \newcommand{\rrB}{\@rr{B}}
1185 \newcommand{\SquareB}{\@tlen\@SquareLetter{\rrB}\@tlen}
1186 \newcommand{\rrhB}{\raisebox{-0.25mm}{\SquareB}}
1187 \newcommand{\RubikB}{\raisebox{\@hRubik}{\SquareB}}
1188 \newcommand{\textRubikB}{\rrhB}
```

20.21.6 Rotation Bp

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

`\SquareBp`

`\rrhBp` 1189 \newcommand{\rrBp}{\@rrp{B}}

`\RubikBp` 1190 \newcommand{\SquareBp}{\@tlen\@SquareLetter{\rrBp}\@tlen}

`\textRubikBp` 1191 \newcommand{\rrhBp}{\raisebox{-0.25mm}{\SquareBp}}

1192 \newcommand{\RubikBp}{\raisebox{\@hRubik}{\SquareBp}}

1193 \newcommand{\textRubikBp}{\rrhBp}

20.21.7 Rotation Bw

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

`\SquareBw`

`\rrhBw` 1194 \newcommand{\rrBw}{\@rrw{B}}

`\RubikBw` 1195 \newcommand{\SquareBw}{\@tlen\@SquareLetter{\rrBw}\@tlen}

`\textRubikBw` 1196 \newcommand{\rrhBw}{\raisebox{-0.25mm}{\SquareBw}}

1197 \newcommand{\RubikBw}{\raisebox{\@hRubik}{\SquareBw}}

1198 \newcommand{\textRubikBw}{\rrhBw}

20.21.8 Rotation Bwp

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

`\SquareBwp`

`\rrhBwp`

`\RubikBwp`

`\textRubikBwp`

```

1199 \newcommand{\rrBwp}{\@rrwp{B}}
1200 \newcommand{\SquareBwp}{\@tlen\@SquareLetter{\rrBwp}\@tlen}
1201 \newcommand{\rrhBwp}{\raisebox{-0.25mm}{\SquareBwp}}
1202 \newcommand{\RubikBwp}{\raisebox{\@hRubik}{\SquareBwp}}
1203 \newcommand{\textRubikBwp}{\rrhBwp}

```

20.21.9 Rotation Bs

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

`\SquareBs`

`\rrhBs` 1204 \newcommand{\rrBs}{\@rrs{B}}

`\RubikBs` 1205 \newcommand{\SquareBs}{\@tlen\@SquareLetter{\rrBs}\@tlen}

`\textRubikBs` 1206 \newcommand{\rrhBs}{\raisebox{-0.25mm}{\SquareBs}}

1207 \newcommand{\RubikBs}{\raisebox{\@hRubik}{\SquareBs}}

1208 \newcommand{\textRubikBs}{\rrhBs}

20.21.10 Rotation Bsp

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

`\SquareBsp`

`\rrhBsp` 1209 \newcommand{\rrBsp}{\@rrsp{B}}

`\RubikBsp` 1210 \newcommand{\SquareBsp}{\@tlen\@SquareLetter{\rrBsp}\@tlen}

`\textRubikBsp` 1211 \newcommand{\rrhBsp}{\raisebox{-0.25mm}{\SquareBsp}}

1212 \newcommand{\RubikBsp}{\raisebox{\@hRubik}{\SquareBsp}}

1213 \newcommand{\textRubikBsp}{\rrhBsp}

20.21.11 Rotation Ba

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

`\SquareBa`

`\rrhBa` 1214 \newcommand{\rrBa}{\@rra{B}}

`\RubikBa` 1215 \newcommand{\SquareBa}{\@tlen\@SquareLetter{\rrBa}\@tlen}

`\textRubikBa` 1216 \newcommand{\rrhBa}{\raisebox{-0.25mm}{\SquareBa}}

1217 \newcommand{\RubikBa}{\raisebox{\@hRubik}{\SquareBa}}

1218 \newcommand{\textRubikBa}{\rrhBa}

20.21.12 Rotation Bap

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

`\SquareBap`

`\rrhBap` 1219 \newcommand{\rrBap}{\@rrap{B}}

`\RubikBap` 1220 \newcommand{\SquareBap}{\@tlen\@SquareLetter{\rrBap}\@tlen}

`\textRubikBap` 1221 \newcommand{\rrhBap}{\raisebox{-0.25mm}{\SquareBap}}

1222 \newcommand{\RubikBap}{\raisebox{\@hRubik}{\SquareBap}}

1223 \newcommand{\textRubikBap}{\rrhBap}

20.21.13 Rotation D

`\rrD` These commands all draw forms which denote the D rotation.

`\SquareD` Feb 2017 (RWDN): added the `\@tlen` length to the `\rrhD` command to improve the spacing between two ‘arrow’ square hieroglyphs; and also removed the

`\rrhD` terminal `\`, space. The same changes were made to all the ‘arrow’ hieroglyphs.

`\RubikD`

`\textRubikD`

```

1224 \newcommand{\rrD}{\@rr{D}}
1225 %%
1226 \newcommand{\SquareD}{%
1227 \begin{tikzpicture}[scale=0.5]
1228 \DrawNotationBox;
1229 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1230 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1231 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1232 \end{tikzpicture}%
1233 }
1234 \newcommand{\rrhD}{\raisebox{-0.333\height}{\@tlen\SquareD\@tlen}}
1235 %%
1236 \newcommand{\RubikD}{%
1237 {\@rubikfont%
1238 \begin{minipage}{0.6cm}
1239 \centering%
1240 \SquareD\
1241 \rrD%
1242 \end{minipage}%
1243 }}
1244 \newcommand{\textRubikD}{\rrD\,\rrhD}
```

20.21.14 Rotation Dp

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

`\SquareDp`

`\rrhDp`

`\RubikDp`

`\textRubikDp`

```

1245 \newcommand{\rrDp}{\@rrp{D}}
1246 %%
1247 \newcommand{\SquareDp}{%
1248 \begin{tikzpicture}[scale=0.5]
1249 \DrawNotationBox;
1250 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1251 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1252 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1253 \end{tikzpicture}%
1254 }
1255 \newcommand{\rrhDp}{\raisebox{-0.333\height}{\@tlen\SquareDp\@tlen}}
1256 %%
1257 \newcommand{\RubikDp}{%
1258 {\@rubikfont%
1259 \begin{minipage}{0.6cm}
1260 \centering%
1261 \SquareDp\
1262 \rrDp%
```

```

1263 \end{minipage}%
1264 }}
1265 \newcommand{\textRubikDp}{\rrDp\,\rrhDp}

```

20.21.15 Rotation Dw

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

```

\SquareDw 1266 \newcommand{\rrDw}{\@rrw{D}}
\rrhDw 1267 %%
\RubikDw 1268 \newcommand{\SquareDw}{%
\textRubikDw 1269 \begin{tikzpicture}[scale=0.5]
1270 \DrawNotationBox;
1271 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1272 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1273 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1274 \end{tikzpicture}%
1275 }
1276 \newcommand{\rrhDw}{\raisebox{-0.333\height}{\@tlen\SquareDw\@tlen}}
1277 %%
1278 \newcommand{\RubikDw}{%
1279 {\@rubikfont%
1280 \begin{minipage}{0.6cm}
1281 \centering%
1282 \SquareDw\
1283 \rrDw%
1284 \end{minipage}%
1285 }}
1286 \newcommand{\textRubikDw}{\rrDw\,\rrhDw}

```

20.21.16 Rotation Dwp

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

```

\SquareDwp 1287 \newcommand{\rrDwp}{\@rrwp{D}}
\rrhDwp 1288 %%
\RubikDwp 1289 \newcommand{\SquareDwp}{%
\textRubikDwp 1290 \begin{tikzpicture}[scale=0.5]
1291 \DrawNotationBox;
1292 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1293 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1294 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1295 \end{tikzpicture}%
1296 }
1297 \newcommand{\rrhDwp}{\raisebox{-0.333\height}{\@tlen\SquareDwp\@tlen}}
1298 %%
1299 \newcommand{\RubikDwp}{%
1300 {\@rubikfont%
1301 \begin{minipage}{0.6cm}
1302 \centering%
1303 \SquareDwp\

```

```

1304 \rrDwp%
1305 \end{minipage}%
1306 }}
1307 \newcommand{\textRubikDwp}{\rrDwp\,\rrhDwp}

```

20.21.17 Rotation Ds

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

```

\SquareDs 1308 \newcommand{\rrDs}{\@rrs{D}}
\rrhDs    1309 %%
\RubikDs  1310 \newcommand{\SquareDs}{%
\textRubikDs 1311 \begin{tikzpicture}[scale=0.5]
1312 \DrawNotationBox;
1313 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1314 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);
1315 \draw [thick, ->]  (\@sb,\@sd) -- (\@sbh, \@sd);
1316 \end{tikzpicture}%
1317 }
1318 \newcommand{\rrhDs}{\raisebox{-0.333\height}{\@tlen\SquareDs\@tlen}}
1319 %%
1320 \newcommand{\RubikDs}{%
1321 {\@rubikfont%
1322 \begin{minipage}{0.6cm}
1323 \centering%
1324 \SquareDs\
1325 \rrDs%
1326 \end{minipage}%
1327 }}
1328 \newcommand{\textRubikDs}{\rrDs\,\rrhDs}

```

20.21.18 Rotation Dsp

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

```

\SquareDsp 1329 \newcommand{\rrDsp}{\@rrsp{D}}
\rrhDsp    1330 %%
\RubikDsp  1331 \newcommand{\SquareDsp}{%
\textRubikDsp 1332 \begin{tikzpicture}[scale=0.5]
1333 \DrawNotationBox;
1334 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1335 \draw [thick]      (\@sb,\@sdd) -- (\@sbh, \@sdd);
1336 \draw [thick, <-]  (\@sb,\@sd) -- (\@sbh, \@sd);
1337 \end{tikzpicture}%
1338 }
1339 \newcommand{\rrhDsp}{\raisebox{-0.333\height}{\@tlen\SquareDsp\@tlen}}
1340 %%
1341 \newcommand{\RubikDsp}{%
1342 {\@rubikfont%
1343 \begin{minipage}{0.6cm}
1344 \centering%

```

```

1345 \SquareDsp\\
1346 \rrDsp%
1347 \end{minipage}%
1348 }}
1349 \newcommand{\textRubikDsp}{\rrDsp\,\rrhDsp}

```

20.21.19 Rotation Da

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

```

\SquareDa 1350 \newcommand{\rrDa}{\@rra{D}}
\rrhDa 1351 %%
\RubikDa 1352 \newcommand{\SquareDa}{%
\textRubikDa 1353 \begin{tikzpicture}[scale=0.5]
1354 \DrawNotationBox;
1355 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1356 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1357 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1358 \end{tikzpicture}%
1359 }
1360 \newcommand{\rrhDa}{\raisebox{-0.333\height}{\@tlen\SquareDa\@tlen}}
1361 %%
1362 \newcommand{\RubikDa}{%
1363 {\@rubikfont%
1364 \begin{minipage}{0.6cm}
1365 \centering%
1366 \SquareDa\\
1367 \rrDa%
1368 \end{minipage}%
1369 }}
1370 \newcommand{\textRubikDa}{\rrDa\,\rrhDa}

```

20.21.20 Rotation Dap

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

```

\SquareDap 1371 \newcommand{\rrDap}{\@rrap{D}}
\rrhDap 1372 %%
\RubikDap 1373 \newcommand{\SquareDap}{%
\textRubikDap 1374 \begin{tikzpicture}[scale=0.5]
1375 \DrawNotationBox;
1376 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1377 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1378 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1379 \end{tikzpicture}%
1380 }
1381 \newcommand{\rrhDap}{\raisebox{-0.333\height}{\@tlen\SquareDap\@tlen}}
1382 %%
1383 \newcommand{\RubikDap}{%
1384 {\@rubikfont%
1385 \begin{minipage}{0.6cm}

```

```

1386 \centering%
1387 \SquareDap\
1388 \rrDap%
1389 \end{minipage}%
1390 }}
1391 \newcommand{\textRubikDap}{\rrDap\,\rrhDap}

```

20.21.21 Rotation E

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

```

\SquareE 1392 \newcommand{\rrE}{\@rr{E}}
\rrhE    1393 %%
\RubikE  1394 \newcommand{\SquareE}{%
\textRubikE 1395 \begin{tikzpicture}[scale=0.5]
1396 \DrawNotationBox;
1397 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1398 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1399 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1400 \end{tikzpicture}%
1401 }
1402 \newcommand{\rrhE}{\raisebox{-0.333\height}{\@tlen\SquareE\@tlen}}
1403 %%
1404 \newcommand{\RubikE}{%
1405 {\@rubikfont%
1406 \begin{minipage}{0.6cm}
1407 \centering%
1408 \SquareE\
1409 \rrE%
1410 \end{minipage}%
1411 }}
1412 \newcommand{\textRubikE}{\rrE\,\rrhE}

```

20.21.22 Rotation Ep

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

```

\SquareEp 1413 \newcommand{\rrEp}{\@rrp{E}}
\rrhEp    1414 %%
\RubikEp  1415 \newcommand{\SquareEp}{%
\textRubikEp 1416 \begin{tikzpicture}[scale=0.5]
1417 \DrawNotationBox;
1418 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1419 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1420 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1421 \end{tikzpicture}%
1422 }
1423 \newcommand{\rrhEp}{\raisebox{-0.333\height}{\@tlen\SquareEp\@tlen}}
1424 %%
1425 \newcommand{\RubikEp}{%
1426 {\@rubikfont%

```



```

1427 \begin{minipage}{0.6cm}
1428 \centering%
1429 \SquareEp\
1430 \rrEp%
1431 \end{minipage}%
1432 }}
1433 \newcommand{\textRubikEp}{\rrEp\,\rrhEp}

```

20.21.23 Rotation F

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

```

\SquareF 1434 \newcommand{\rrF}{\@rr{F}}
\rrhF    1435 %%
\RubikF  1436 \newcommand{\SquareF}{%
\textRubikF 1437 \begin{tikzpicture}[scale=0.5]
1438 \DrawNotationBox;
1439 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1440 \end{tikzpicture}%
1441 }
1442 \newcommand{\rrhF}{\raisebox{-0.333\height}{\@tlen\SquareF\@tlen}}
1443 %%
1444 \newcommand{\RubikF}{%
1445 {\@rubikfont%
1446 \begin{minipage}{0.6cm}
1447 \centering%
1448 \SquareF\
1449 \rrF%
1450 \end{minipage}%
1451 }}
1452 \newcommand{\textRubikF}{\rrF\,\rrhF}

```

20.21.24 Rotation Fp

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

```

\SquareFp 1453 \newcommand{\rrFp}{\@rrp{F}}
\rrhFp    1454 %%
\RubikFp  1455 \newcommand{\SquareFp}{%
\textRubikFp 1456 \begin{tikzpicture}[scale=0.5]
1457 \DrawNotationBox;
1458 \draw [thick, ->] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1459 \end{tikzpicture}%
1460 }
1461 \newcommand{\rrhFp}{\raisebox{-0.333\height}{\@tlen\SquareFp\@tlen}}
1462 %%
1463 \newcommand{\RubikFp}{%
1464 {\@rubikfont%
1465 \begin{minipage}{0.6cm}
1466 \centering%
1467 \SquareFp\

```

```

1468 \rrFp%
1469 \end{minipage}%
1470 }}
1471 \newcommand{\textRubikFp}{\rrFp\,\rrhFp}

```

20.21.25 Rotation Fw

```

\rrFw These commands all draw forms which denote the Fw rotation.
\SquareFw 1472 \newcommand{\rrFw}{\@rrw{F}}
\rrhFw 1473 %%
\RubikFw 1474 \newcommand{\SquareFw}{%
\textRubikFw 1475 \begin{tikzpicture}[scale=0.5]
1476 \DrawNotationBox;
1477 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1478 \draw [thick] (\@sqcx,\@sqcy) arc[radius=0.1, start angle=-60, delta angle=360];
1479 %\node (squareLab) at (0.5,0.5) {$o$};
1480 \end{tikzpicture}%
1481 }
1482 \newcommand{\rrhFw}{\raisebox{-0.333\height}{\@tlen\SquareFw\@tlen}}
1483 %%
1484 \newcommand{\RubikFw}{%
1485 {\@rubikfont%
1486 \begin{minipage}{0.6cm}
1487 \centering%
1488 \SquareFw\
1489 \rrFw%
1490 \end{minipage}%
1491 }}
1492 \newcommand{\textRubikFw}{\rrFw\,\rrhFw}

```

20.21.26 Rotation Fwp

```

\rrFwp These commands all draw forms which denote the Fwp rotation.
\SquareFwp 1493 \newcommand{\rrFwp}{\@rrwp{F}}
\rrhFwp 1494 %%
\RubikFwp 1495 \newcommand{\SquareFwp}{%
\textRubikFwp 1496 \begin{tikzpicture}[scale=0.5]
1497 \DrawNotationBox;
1498 \draw [thick, ->] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1499 \draw [thick] (\@sqcx,\@sqcy) arc[radius=0.1, start angle=-60, delta angle=360];
1500 \end{tikzpicture}%
1501 }
1502 \newcommand{\rrhFwp}{\raisebox{-0.333\height}{\@tlen\SquareFwp\@tlen}}
1503 %%
1504 \newcommand{\RubikFwp}{%
1505 {\@rubikfont%
1506 \begin{minipage}{0.6cm}
1507 \centering%
1508 \SquareFwp\

```

```

1509 \rrFwp%
1510 \end{minipage}%
1511 }}
1512 \newcommand{\textRubikFwp}{\rrFwp\,\rrhFwp}
1513 %%

```

20.21.27 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.

```

1514 \newcommand{\rrFs}{\@rrs{F}}
1515 \newcommand{\SquareFs}{\@tlen\@SquareLetter{\rrFs}\@tlen}
1516 \newcommand{\rrhFs}{\raisebox{-0.25mm}{\SquareFs}}
1517 \newcommand{\RubikFs}{\raisebox{\@hRubik}{\SquareFs}}
1518 \newcommand{\textRubikFs}{\rrhFs}

```

20.21.28 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.

```

1519 \newcommand{\rrFsp}{\@rrsp{F}}
1520 \newcommand{\SquareFsp}{\@tlen\@SquareLetter{\rrFsp}\@tlen}
1521 \newcommand{\rrhFsp}{\raisebox{-0.25mm}{\SquareFsp}}
1522 \newcommand{\RubikFsp}{\raisebox{\@hRubik}{\SquareFsp}}
1523 \newcommand{\textRubikFsp}{\rrhFsp}

```

20.21.29 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.

```

1524 \newcommand{\rrFa}{\@rra{F}}
1525 \newcommand{\SquareFa}{\@tlen\@SquareLetter{\rrFa}\@tlen}
1526 \newcommand{\rrhFa}{\raisebox{-0.25mm}{\SquareFa}}
1527 \newcommand{\RubikFa}{\raisebox{\@hRubik}{\SquareFa}}
1528 \newcommand{\textRubikFa}{\rrhFa}

```

20.21.30 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.

```

1529 \newcommand{\rrFap}{\@rrap{F}}
1530 \newcommand{\SquareFap}{\@tlen\@SquareLetter{\rrFap}\@tlen}
1531 \newcommand{\rrhFap}{\raisebox{-0.25mm}{\SquareFap}}
1532 \newcommand{\RubikFap}{\raisebox{\@hRubik}{\SquareFap}}
1533 \newcommand{\textRubikFap}{\rrhFap}

```

20.21.31 Rotation L

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

```

\SquareL 1534 \newcommand{\rrL}{\@rr{L}}
\rrhL    1535 %%
\RubikL  1536 \newcommand{\SquareL}{%
\textRubikL 1537 \begin{tikzpicture}[scale=0.5]
1538 \DrawNotationBox;
1539 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1540 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1541 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1542 \end{tikzpicture}%
1543 }
1544 \newcommand{\rrhL}{\raisebox{-0.333\height}{\@tlen\SquareL\@tlen}}
1545 %%
1546 \newcommand{\RubikL}{%
1547 {\@rubikfont%
1548 \begin{minipage}{0.6cm}
1549 \centering%
1550 \SquareL\
1551 \rrL%
1552 \end{minipage}%
1553 }}
1554 \newcommand{\textRubikL}{\rrL\,\rrhL}

```

20.21.32 Rotation Lp

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

```

\SquareLp 1555 \newcommand{\rrLp}{\@rrp{L}}
\rrhLp    1556 %%
\RubikLp  1557 \newcommand{\SquareLp}{%
\textRubikLp 1558 \begin{tikzpicture}[scale=0.5]
1559 \DrawNotationBox;
1560 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1561 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1562 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1563 \end{tikzpicture}%
1564 }
1565 \newcommand{\rrhLp}{\raisebox{-0.333\height}{\@tlen\SquareLp\@tlen}}
1566 %%
1567 \newcommand{\RubikLp}{%
1568 {\@rubikfont%
1569 \begin{minipage}{0.6cm}

```

```

1570 \centering%
1571 \SquareLp\
1572 \rrLp%
1573 \end{minipage}%
1574 }}
1575 \newcommand{\textRubikLp}{\rrLp\,\rrhLp}

```

20.21.33 Rotation Lw

```

\rrLw These commands all draw forms which denote the Lw rotation.
\SquareLw 1576 \newcommand{\rrLw}{\@rrw{L}}
\rrhLw 1577 %%
\RubikLw 1578 \newcommand{\SquareLw}{%
\textRubikLw 1579 \begin{tikzpicture}[scale=0.5]
1580 \DrawNotationBox;
1581 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1582 \draw [thick, <-] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1583 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1584 \end{tikzpicture}%
1585 }
1586 \newcommand{\rrhLw}{\raisebox{-0.333\height}{\@tlen\SquareLw\@tlen}}
1587 %%
1588 \newcommand{\RubikLw}{%
1589 {\@rubikfont%
1590 \begin{minipage}{0.6cm}
1591 \centering%
1592 \SquareLw\
1593 \rrLw%
1594 \end{minipage}%
1595 }}
1596 \newcommand{\textRubikLw}{\rrLw\,\rrhLw}

```

20.21.34 Rotation Lwp

```

\rrLwp These commands all draw forms which denote the Lwp rotation.
\SquareLwp 1597 \newcommand{\rrLwp}{\@rrwp{L}}
\rrhLwp 1598 %%
\RubikLwp 1599 \newcommand{\SquareLwp}{%
\textRubikLwp 1600 \begin{tikzpicture}[scale=0.5]
1601 \DrawNotationBox;
1602 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1603 \draw [thick,->] (\@sdd, \@sb) -- (\@sdd, \@sbh);
1604 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1605 \end{tikzpicture}%
1606 }
1607 \newcommand{\rrhLwp}{\raisebox{-0.333\height}{\@tlen\SquareLwp\@tlen}}
1608 %%
1609 \newcommand{\RubikLwp}{%
1610 {\@rubikfont%

```

```

1611 \begin{minipage}{0.6cm}
1612 \centering%
1613 \SquareLwp\
1614 \rrLwp%
1615 \end{minipage}%
1616 }}
1617 \newcommand{\textRubikLwp}{\rrLwp\,\rrhLwp}

```

20.21.35 Rotation Ls

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

```

\SquareLs 1618 \newcommand{\rrLs}{\@rrs{L}}
\rrhLs 1619 %%
\RubikLs 1620 \newcommand{\SquareLs}{%
\textRubikLs 1621 \begin{tikzpicture}[scale=0.5]
1622 \DrawNotationBox;
1623 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1624 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1625 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1626 \end{tikzpicture}%
1627 }
1628 \newcommand{\rrhLs}{\raisebox{-0.333\height}{\@tlen\SquareLs\@tlen}}
1629 %%
1630 \newcommand{\RubikLs}{%
1631 {\@rubikfont%
1632 \begin{minipage}{0.6cm}
1633 \centering%
1634 \SquareLs\
1635 \rrLs%
1636 \end{minipage}%
1637 }}
1638 \newcommand{\textRubikLs}{\rrLs\,\rrhLs}

```

20.21.36 Rotation Lsp

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

```

\SquareLsp 1639 \newcommand{\rrLsp}{\@rrsp{L}}
\rrhLsp 1640 %%
\RubikLsp 1641 \newcommand{\SquareLsp}{%
\textRubikLsp 1642 \begin{tikzpicture}[scale=0.5]
1643 \DrawNotationBox;
1644 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1645 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1646 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1647 \end{tikzpicture}%
1648 }
1649 \newcommand{\rrhLsp}{\raisebox{-0.333\height}{\@tlen\SquareLsp\@tlen}}
1650 %%
1651 \newcommand{\RubikLsp}{%

```

```

1652 {\@rubikfont%
1653 \begin{minipage}{0.6cm}
1654 \centering%
1655 \SquareLsp\
1656 \rrLsp%
1657 \end{minipage}%
1658 }}
1659 \newcommand{\textRubikLsp}{\rrLsp\,\rrhLsp}

```

20.21.37 Rotation La

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

```

\SquareLa 1660 \newcommand{\rrLa}{\@rra{L}}
\rrhLa    1661 %%
\RubikLa  1662 \newcommand{\SquareLa}{%
\textRubikLa 1663 \begin{tikzpicture}[scale=0.5]
1664 \DrawNotationBox;
1665 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1666 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1667 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1668 \end{tikzpicture}%
1669 }
1670 \newcommand{\rrhLa}{\raisebox{-0.333\height}{\@tlen\SquareLa\@tlen}}
1671 %%
1672 \newcommand{\RubikLa}{%
1673 {\@rubikfont%
1674 \begin{minipage}{0.6cm}
1675 \centering%
1676 \SquareLa\
1677 \rrLa%
1678 \end{minipage}%
1679 }}
1680 \newcommand{\textRubikLa}{\rrLa\,\rrhLa}

```

20.21.38 Rotation Lap

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

```

\SquareLap 1681 \newcommand{\rrLap}{\@rrap{L}}
\rrhLap    1682 %%
\RubikLap  1683 \newcommand{\SquareLap}{%
\textRubikLap 1684 \begin{tikzpicture}[scale=0.5]
1685 \DrawNotationBox;
1686 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1687 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1688 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1689 \end{tikzpicture}%
1690 }
1691 \newcommand{\rrhLap}{\raisebox{-0.333\height}{\@tlen\SquareLap\@tlen}}
1692 %%

```

```

1693 \newcommand{\RubikLap}{%
1694 {\@rubikfont%
1695 \begin{minipage}{0.6cm}
1696 \centering%
1697 \SquareLap\\
1698 \rrLap%
1699 \end{minipage}%
1700 }}
1701 \newcommand{\textRubikLap}{\rrLap\,\,\rrhLap}

```

20.21.39 Rotation M

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

```

\SquareM 1702 \newcommand{\rrM}{\@rr{M}}
\rrhM    1703 %%
\RubikM  1704 \newcommand{\SquareM}{%
\textRubikM 1705 \begin{tikzpicture}[scale=0.5]
1706 \DrawNotationBox;
1707 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1708 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1709 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1710 \end{tikzpicture}%
1711 }
1712 \newcommand{\rrhM}{\raisebox{-0.333\height}{\@tlen\SquareM\@tlen}}
1713 %%
1714 \newcommand{\RubikM}{%
1715 {\@rubikfont%
1716 \begin{minipage}{0.6cm}
1717 \centering%
1718 \SquareM\\
1719 \rrM%
1720 \end{minipage}%
1721 }}
1722 \newcommand{\textRubikM}{\rrM\,\,\rrhM}

```

20.21.40 Rotation Mp

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

```

\SquareMp 1723 \newcommand{\rrMp}{\@rrp{M}}
\rrhMp    1724 %%
\RubikMp  1725 \newcommand{\SquareMp}{%
\textRubikMp 1726 \begin{tikzpicture}[scale=0.5]
1727 \DrawNotationBox;
1728 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1729 \draw [thick,->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1730 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1731 \end{tikzpicture}%
1732 }
1733 \newcommand{\rrhMp}{\raisebox{-0.333\height}{\@tlen\SquareMp\@tlen}}

```



```

1734 %%
1735 \newcommand{\RubikMp}{%
1736 {\@rubikfont%
1737 \begin{minipage}{0.6cm}
1738 \centering%
1739 \SquareMp\
1740 \rrMp%
1741 \end{minipage}%
1742 }}
1743 \newcommand{\textRubikMp}{\rrMp\,\rrhMp}

```

20.21.41 Rotation R

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

```

\SquareR 1744 \newcommand{\rrR}{\@rr{R}}
\rrhR    1745 %%
\RubikR  1746 \newcommand{\SquareR}{%
\textRubikR 1747 \begin{tikzpicture}[scale=0.5]
1748 \DrawNotationBox;
1749 %% draw three lines in the square, one with an arrow
1750 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1751 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1752 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1753 \end{tikzpicture}%
1754 }
1755 \newcommand{\rrhR}{\raisebox{-0.333\height}{\@tlen\SquareR\@tlen}}
1756 %%
1757 \newcommand{\RubikR}{%
1758 {\@rubikfont%
1759 \begin{minipage}{0.6cm}
1760 \centering%
1761 \SquareR\
1762 \rrR%
1763 \end{minipage}%
1764 }}
1765 \newcommand{\textRubikR}{\rrR\,\rrhR}

```

20.21.42 Rotation Rp

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

```

\SquareRp 1766 \newcommand{\rrRp}{\@rrp{R}}
\rrhRp    1767 %%
\RubikRp  1768 \newcommand{\SquareRp}{%
\textRubikRp 1769 \begin{tikzpicture}[scale=0.5]
1770 \DrawNotationBox;
1771 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1772 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1773 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1774 \end{tikzpicture}%

```

```

1775 }
1776 \newcommand{\rrhRp}{\raisebox{-0.333\height}{\@tlen\SquareRp\@tlen}}
1777 %%
1778 \newcommand{\RubikRp}{%
1779 {\@rubikfont%
1780 \begin{minipage}{0.6cm}
1781 \centering%
1782 \SquareRp\
1783 \rrRp%
1784 \end{minipage}%
1785 }}
1786 \newcommand{\textRubikRp}{\rrRp\,\rrhRp}

```

20.21.43 Rotation Rw

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

```

\SquareRw 1787 \newcommand{\rrRw}{\@rrw{R}}
\rrhRw    1788 %%
\RubikRw  1789 \newcommand{\SquareRw}{%
\textRubikRw 1790 \begin{tikzpicture}[scale=0.5]
1791 \DrawNotationBox;
1792 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1793 \draw [thick, ->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1794 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1795 \end{tikzpicture}%
1796 }
1797 \newcommand{\rrhRw}{\raisebox{-0.333\height}{\@tlen\SquareRw\@tlen}}
1798 %%
1799 \newcommand{\RubikRw}{%
1800 {\@rubikfont%
1801 \begin{minipage}{0.6cm}
1802 \centering%
1803 \SquareRw\
1804 \rrRw%
1805 \end{minipage}%
1806 }}
1807 \newcommand{\textRubikRw}{\rrRw\,\rrhRw}

```

20.21.44 Rotation Rwp

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

```

\SquareRwp 1808 \newcommand{\rrRwp}{\@rrwp{R}}
\rrhRwp    1809 %%
\RubikRwp  1810 \newcommand{\SquareRwp}{%
\textRubikRwp 1811 \begin{tikzpicture}[scale=0.5]
1812 \DrawNotationBox;
1813 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1814 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1815 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);

```

```

1816 \end{tikzpicture}%
1817 }
1818 \newcommand{\rrhRwp}{\raisebox{-0.333\height}{\@tlen\SquareRwp\@tlen}}
1819 %%
1820 \newcommand{\RubikRwp}{%
1821 {\@rubikfont%
1822 \begin{minipage}{0.6cm}
1823 \centering%
1824 \SquareRwp\
1825 \rrRwp%
1826 \end{minipage}%
1827 }}
1828 \newcommand{\textRubikRwp}{\rrRwp\,\rrhRwp}

```

20.21.45 Rotation Rs

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

```

\SquareRs 1829 \newcommand{\rrRs}{\@rrs{R}}
\rrhRs    1830 %%
\RubikRs  1831 \newcommand{\SquareRs}{%
\textRubikRs 1832 \begin{tikzpicture}[scale=0.5]
1833 \DrawNotationBox;
1834 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1835 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1836 \draw [thick,->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1837 \end{tikzpicture}%
1838 }
1839 \newcommand{\rrhRs}{\raisebox{-0.333\height}{\@tlen\SquareRs\@tlen}}
1840 %%
1841 \newcommand{\RubikRs}{%
1842 {\@rubikfont%
1843 \begin{minipage}{0.6cm}
1844 \centering%
1845 \SquareRs\
1846 \rrRs%
1847 \end{minipage}%
1848 }}
1849 \newcommand{\textRubikRs}{\rrRs\,\rrhRs}

```

20.21.46 Rotation Rsp

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

```

\SquareRsp 1850 \newcommand{\rrRsp}{\@rrrsp{R}}
\rrhRsp    1851 %%
\RubikRsp  1852 \newcommand{\SquareRsp}{%
\textRubikRsp 1853 \begin{tikzpicture}[scale=0.5]
1854 \DrawNotationBox;
1855 \draw [thick,<-] (\@sd, \@sb) -- (\@sd, \@sbh);
1856 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);

```

```

1857 \draw [thick,<-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1858 \end{tikzpicture}%
1859 }
1860 \newcommand{\rrhRsp}{\raisebox{-0.333\height}{\@tlen\SquareRsp\@tlen}}
1861 %%
1862 \newcommand{\RubikRsp}{%
1863 {\@rubikfont%
1864 \begin{minipage}{0.6cm}
1865 \centering%
1866 \SquareRsp\
1867 \rrRsp%
1868 \end{minipage}%
1869 }}
1870 \newcommand{\textRubikRsp}{\rrRsp\,\rrhRsp}

```

20.21.47 Rotation Ra

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

```

\SquareRa 1871 \newcommand{\rrRa}{\@rra{R}}
\rrhRa    1872 %%
\RubikRa  1873 \newcommand{\SquareRa}{%
\textRubikRa 1874 \begin{tikzpicture}[scale=0.5]
1875 \DrawNotationBox;
1876 \draw [thick,<-] (\@sd, \@sb) -- (\@sd, \@sbh);
1877 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1878 \draw [thick,->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1879 \end{tikzpicture}%
1880 }
1881 \newcommand{\rrhRa}{\raisebox{-0.333\height}{\@tlen\SquareRa\@tlen}}
1882 %%
1883 \newcommand{\RubikRa}{%
1884 {\@rubikfont%
1885 \begin{minipage}{0.6cm}
1886 \centering%
1887 \SquareRa\
1888 \rrRa%
1889 \end{minipage}%
1890 }}
1891 \newcommand{\textRubikRa}{\rrRa\,\rrhRa}

```

20.21.48 Rotation Rap

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

```

\SquareRap 1892 \newcommand{\rrRap}{\@rrap{R}}
\rrhRap    1893 %%
\RubikRap  1894 \newcommand{\SquareRap}{%
\textRubikRap 1895 \begin{tikzpicture}[scale=0.5]
1896 \DrawNotationBox;
1897 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);

```

```

1898 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1899 \draw [thick,<-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1900 \end{tikzpicture}%
1901 }
1902 \newcommand{\rrhRap}{\raisebox{-0.333\height}{\@tlen\SquareRap\@tlen}}
1903 %%
1904 \newcommand{\RubikRap}{%
1905 {\@rubikfont%
1906 \begin{minipage}{0.6cm}
1907 \centering%
1908 \SquareRap\\
1909 \rrRap%
1910 \end{minipage}%
1911 }}
1912 \newcommand{\textRubikRap}{\rrRap\,\rrhRap}

```

20.21.49 Rotation S

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

`\rrhS` 1913 \newcommand{\rrS}{\@rr{S}}

`\RubikS` 1914 \newcommand{\SquareS}{\@tlen\SquareLetter{\rrS}\@tlen}

`\textRubikS` 1915 \newcommand{\rrhS}{\raisebox{-0.25mm}{\SquareS}}

1916 \newcommand{\RubikS}{\raisebox{\@hRubik}{\SquareS}}

1917 \newcommand{\textRubikS}{\rrhS}

20.21.50 Rotation Sp

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

`\rrhSp` 1918 \newcommand{\rrSp}{\@rrp{S}}

`\RubikSp` 1919 \newcommand{\SquareSp}{\@tlen\SquareLetter{\rrSp}\@tlen}

`\textRubikSp` 1920 \newcommand{\rrhSp}{\raisebox{-0.25mm}{\SquareSp}}

1921 \newcommand{\RubikSp}{\raisebox{\@hRubik}{\SquareSp}}

1922 \newcommand{\textRubikSp}{\rrhSp}

20.21.51 Rotation Su

`\rrSu` These commands draw forms of the Singmaster Su slice rotation. We also need to fine-tune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).

`\rrhSu`

`\RubikSu` 1923 \newcommand{\rrSu}{\@rru{S}}

`\textRubikSu` 1924 \newcommand{\rrhSu}{\rrhEp}%

1925 \newcommand{\RubikSu}{%
1926 {\@rubikfont%
1927 \begin{minipage}{0.6cm}
1928 \centering%
1929 \SquareEp\\
1930 \rrSu%
1931 \end{minipage}%

```
1932 }}
1933 \newcommand{\textRubikSu}{\rrSu\,\rrhEp}
```

20.21.52 Rotation Sup

`\rrSup` These commands draw forms of the Singmaster Sup slice rotation. We also need
`\rrhSup` to fine-tune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
`\RubikSup` 1934 \newcommand{\rrSup}{\@rrup{S}}
`\textRubikSup` 1935 \newcommand{\rrhSup}{\rrhE}%
1936 \newcommand{\RubikSup}{%
1937 {\@rubikfont%
1938 \begin{minipage}{0.6cm}
1939 \centering%
1940 \SquareE\\
1941 \rrSup%
1942 \end{minipage}%
1943 }}
1944 \newcommand{\textRubikSup}{\rrSup\,\rrhE}

20.21.53 Rotation Sd

`\rrSd` These commands draw forms of the Singmaster Sd slice rotation.
`\rrhSd` 1945 \newcommand{\rrSd}{\@rrd{S}}
`\RubikSd` 1946 \newcommand{\rrhSd}{\rrhE}%
`\textRubikSd` 1947 \newcommand{\RubikSd}{%
1948 {\@rubikfont%
1949 \begin{minipage}{0.6cm}
1950 \centering%
1951 \SquareE\\
1952 \rrSd%
1953 \end{minipage}%
1954 }}
1955 \newcommand{\textRubikSd}{\rrSd\,\rrhE}

20.21.54 Rotation Sdp

`\rrSdp` These commands draw forms of the Singmaster Sdp slice rotation.
`\rrhSdp` 1956 \newcommand{\rrSdp}{\@rrdp{S}}
`\RubikSdp` 1957 \newcommand{\rrhSdp}{\rrhEp}%
`\textRubikSdp` 1958 \newcommand{\RubikSdp}{%
1959 {\@rubikfont%
1960 \begin{minipage}{0.6cm}
1961 \centering%
1962 \SquareEp\\
1963 \rrSdp%
1964 \end{minipage}%
1965 }}
1966 \newcommand{\textRubikSdp}{\rrSdp\,\rrhEp}

20.21.55 Rotation Sl

`\rrSl` These commands draw forms of the Singmaster Sl slice rotation.
`\rrhSl` 1967 `\newcommand{\rrSl}{\@rrl{S}}`
`\RubikSl` 1968 `\newcommand{\rrhSl}{\rrhM}%`
`\textRubikSl` 1969 `\newcommand{\RubikSl}{%`
1970 `{\@rubikfont%`
1971 `\begin{minipage}{0.6cm}`
1972 `\centering%`
1973 `\SquareM\`
1974 `\rrSl%`
1975 `\end{minipage}%`
1976 `}}`
1977 `\newcommand{\textRubikSl}{\rrSl\,\rrhM}`

20.21.56 Rotation Slp

`\rrSlp` These commands draw forms of the Singmaster Slp slice rotation.
`\rrhSlp` 1978 `\newcommand{\rrSlp}{\@rrlp{S}}`
`\RubikSlp` 1979 `\newcommand{\rrhSlp}{\rrhMp}%`
`\textRubikSlp` 1980 `\newcommand{\RubikSlp}{%`
1981 `{\@rubikfont%`
1982 `\begin{minipage}{0.6cm}`
1983 `\centering%`
1984 `\SquareMp\`
1985 `\rrSlp%`
1986 `\end{minipage}%`
1987 `}}`
1988 `\newcommand{\textRubikSlp}{\rrSlp\,\rrhMp}`

20.21.57 Rotation Sr

`\rrSr` These commands draw forms of the Singmaster Sr slice rotation.
`\rrhSr` 1989 `\newcommand{\rrSr}{\@rrr{S}}`
`\RubikSr` 1990 `\newcommand{\rrhSr}{\rrhMp}%`
`\textRubikSr` 1991 `\newcommand{\RubikSr}{%`
1992 `{\@rubikfont%`
1993 `\begin{minipage}{0.6cm}`
1994 `\centering%`
1995 `\SquareMp\`
1996 `\rrSr%`
1997 `\end{minipage}%`
1998 `}}`
1999 `\newcommand{\textRubikSr}{\rrSr\,\rrhMp}`

20.21.58 Rotation Srp

`\rrSrp` These commands draw forms of the Singmaster Srp slice rotation.
`\rrhSrp` 2000 `\newcommand{\rrSrp}{\@rrrp{S}}`
`\RubikSrp`
`\textRubikSrp`

```

2001 \newcommand{\rrhSrp}{\rrhM}%
2002 \newcommand{\RubikSrp}{%
2003 {\@rubikfont%
2004 \begin{minipage}{0.6cm}
2005 \centering%
2006 \SquareM\\
2007 \rrSrp%
2008 \end{minipage}%
2009 }}
2010 \newcommand{\textRubikSrp}{\rrSrp\,\rrhM}

```

20.21.59 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.

```

2011 \newcommand{\rrSf}{\@rrf{S}}
2012 \newcommand{\SquareSf}{\@tlen\@SquareLetter{\rrSf}\@tlen}
2013 \newcommand{\rrhSf}{\raisebox{-0.25mm}{\SquareSf}}
2014 \newcommand{\RubikSf}{\raisebox{\@hRubik}{\SquareSf}}
2015 \newcommand{\textRubikSf}{\rrhSf}

```

20.21.60 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.

```

2016 \newcommand{\rrSfp}{\@rrfp{S}}
2017 \newcommand{\SquareSfp}{\@tlen\@SquareLetter{\rrSfp}\@tlen}
2018 \newcommand{\rrhSfp}{\raisebox{-0.25mm}{\SquareSfp}}
2019 \newcommand{\RubikSfp}{\raisebox{\@hRubik}{\SquareSfp}}
2020 \newcommand{\textRubikSfp}{\rrhSfp}

```

20.21.61 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.

```

2021 \newcommand{\rrSb}{\@rrb{S}}
2022 \newcommand{\SquareSb}{\@tlen\@SquareLetter{\rrSb}\@tlen}
2023 \newcommand{\rrhSb}{\raisebox{-0.25mm}{\SquareSb}}
2024 \newcommand{\RubikSb}{\raisebox{\@hRubik}{\SquareSb}}
2025 \newcommand{\textRubikSb}{\rrhSb}

```


20.21.62 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.

```

2026 \newcommand{\rrSbp}{\@rrbp{S}}
2027 \newcommand{\SquareSbp}{\@tlen\@SquareLetter{\rrSbp}\@tlen}
2028 \newcommand{\rrhSbp}{\raisebox{-0.25mm}{\SquareSbp}}
2029 \newcommand{\RubikSbp}{\raisebox{\@hRubik}{\SquareSbp}}
2030 \newcommand{\textRubikSbp}{\rrhSbp}

```

20.21.63 Rotation U

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

```

\SquareU 2031 \newcommand{\rrU}{\@rr{U}}
\rrhU    2032 %%
\RubikU  2033 \newcommand{\SquareU}{%
\textRubikU 2034 \begin{tikzpicture}[scale=0.5]
2035 \DrawNotationBox;
2036 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh,\@sddd);
2037 \draw [thick]      (\@sb,\@sdd) -- (\@sbh,\@sdd);
2038 \draw [thick]      (\@sb,\@sd) -- (\@sbh,\@sd);
2039 \end{tikzpicture}%
2040 }
2041 \newcommand{\rrhU}{\raisebox{-0.333\height}{\@tlen\SquareU\@tlen}}
2042 %%
2043 \newcommand{\RubikU}{%
2044 {\@rubikfont%
2045 \begin{minipage}{0.6cm}
2046 \centering%
2047 \SquareU\@tlen
2048 \rrU%
2049 \end{minipage}}%
2050 }}
2051 \newcommand{\textRubikU}{\rrU\,\rrhU}

```

20.21.64 Rotation Uw

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

```

\SquareUw 2052 \newcommand{\rrUw}{\@rrw{U}}
\rrhUw    2053 %%
\RubikUw  2054 \newcommand{\SquareUw}{%
\textRubikUw 2055 \begin{tikzpicture}[scale=0.5]
2056 \DrawNotationBox;
2057 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh,\@sddd);
2058 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh,\@sdd);
2059 \draw [thick]      (\@sb,\@sd) -- (\@sbh,\@sd);
2060 \end{tikzpicture}%

```

```

2061 }
2062 %
2063 \newcommand{\rrhUw}{\raisebox{-0.333\height}{\@tlen\SquareUw\@tlen}}
2064 %%
2065 \newcommand{\RubikUw}{%
2066 {\@rubikfont%
2067 \begin{minipage}{0.6cm}
2068 \centering%
2069 \SquareUw\
2070 \rrUw%
2071 \end{minipage}}%%
2072 }}
2073 %%
2074 \newcommand{\textRubikUw}{\rrUw\,\rrhUw}

```

20.21.65 Rotation Up

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

`\SquareUp` 2075 \newcommand{\rrUp}{\@rrp{U}}

`\rrhUp` 2076 %%

`\RubikUp` 2077 \newcommand{\SquareUp}{%

`\textRubikUp` 2078 \begin{tikzpicture}[scale=0.5]

2079 \DrawNotationBox;

2080 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);

2081 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);

2082 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);

2083 \end{tikzpicture}%

2084 }

2085 \newcommand{\rrhUp}{\raisebox{-0.333\height}{\@tlen\SquareUp\@tlen}}

2086 %%

2087 \newcommand{\RubikUp}{%

2088 {\@rubikfont%

2089 \begin{minipage}{0.6cm}

2090 \centering%

2091 \SquareUp\

2092 \rrUp%

2093 \end{minipage}}%%

2094 }}

2095 \newcommand{\textRubikUp}{\rrUp\,\rrhUp}

20.21.66 Rotation Uwp

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

`\SquareUwp` 2096 \newcommand{\rrUwp}{\@rrwp{U}}

`\rrhUwp` 2097 %%

`\RubikUwp` 2098 \newcommand{\SquareUwp}{%

`\textRubikUwp` 2099 \begin{tikzpicture}[scale=0.5]

2100 \DrawNotationBox;

2101 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);

```

2102 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
2103 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
2104 \end{tikzpicture}%
2105 }
2106 \newcommand{\rrhUwp}{\raisebox{-0.333\height}{\@tlen\SquareUwp\@tlen}}
2107 %%
2108 \newcommand{\RubikUwp}{%
2109 {\@rubikfont%
2110 \begin{minipage}{0.6cm}
2111 \centering%
2112 \SquareUwp\
2113 \rrUwp%
2114 \end{minipage}%
2115 }}
2116 \newcommand{\textRubikUwp}{\rrUwp\,\rrhUwp}

```

20.21.67 Rotation Us

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

```

\SquareUs 2117 \newcommand{\rrUs}{\@rrs{U}}
\rrhUs 2118 %%
\RubikUs 2119 \newcommand{\SquareUs}{%
\textRubikUs 2120 \begin{tikzpicture}[scale=0.5]
2121 \DrawNotationBox;
2122 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
2123 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
2124 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
2125 \end{tikzpicture}%
2126 }
2127 \newcommand{\rrhUs}{\raisebox{-0.333\height}{\@tlen\SquareUs\@tlen}}
2128 %%
2129 \newcommand{\RubikUs}{%
2130 {\@rubikfont%
2131 \begin{minipage}{0.6cm}
2132 \centering%
2133 \SquareUs\
2134 \rrUs%
2135 \end{minipage}%
2136 }}
2137 \newcommand{\textRubikUs}{\rrUs\,\rrhUs}

```

20.21.68 Rotation Usp

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

```

\SquareUsp 2138 \newcommand{\rrUsp}{\@rrsp{U}}
\rrhUs 2139 %%
\RubikUs 2140 \newcommand{\SquareUsp}{%
\textRubikUsp 2141 \begin{tikzpicture}[scale=0.5]
2142 \DrawNotationBox;

```

```

2143 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
2144 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
2145 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
2146 \end{tikzpicture}%
2147 }
2148 \newcommand{\rrhUsp}{\raisebox{-0.333\height}{\@tlen\SquareUsp\@tlen}}
2149 %%
2150 \newcommand{\RubikUsp}{%
2151 {\@rubikfont%
2152 \begin{minipage}{0.6cm}
2153 \centering%
2154 \SquareUsp\
2155 \rrUsp%
2156 \end{minipage}%
2157 }}
2158 \newcommand{\textRubikUsp}{\rrUsp\,\rrhUsp}

```

20.21.69 Rotation Ua

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

```

\SquareUa 2159 \newcommand{\rrUa}{\@rra{U}}
\rrhUa    2160 %%
\RubikUa  2161 \newcommand{\SquareUa}{%
\textRubikUa 2162 \begin{tikzpicture}[scale=0.5]
2163 \DrawNotationBox;
2164 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
2165 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
2166 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
2167 \end{tikzpicture}%
2168 }
2169 \newcommand{\rrhUa}{\raisebox{-0.333\height}{\@tlen\SquareUa\@tlen}}
2170 %%
2171 \newcommand{\RubikUa}{%
2172 {\@rubikfont%
2173 \begin{minipage}{0.6cm}
2174 \centering%
2175 \SquareUa\
2176 \rrUa%
2177 \end{minipage}%
2178 }}
2179 \newcommand{\textRubikUa}{\rrUa\,\rrhUa}

```

20.21.70 Rotation Uap

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

```

\SquareUap 2180 \newcommand{\rrUap}{\@rrap{U}}
\rrhUap    2181 %%
\RubikUap  2182 \newcommand{\SquareUap}{%
\textRubikUap 2183 \begin{tikzpicture}[scale=0.5]

```

```

2184 \DrawNotationBox;
2185 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
2186 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
2187 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
2188 \end{tikzpicture}%
2189 }
2190 \newcommand{\rrhUap}{\raisebox{-0.333\height}{\@tlen\SquareUap\@tlen}}
2191 %%
2192 \newcommand{\RubikUap}{%
2193 {\@rubikfont%
2194 \begin{minipage}{0.6cm}
2195 \centering%
2196 \SquareUap\
2197 \rrUap%
2198 \end{minipage}%
2199 }}
2200 \newcommand{\textRubikUap}{\rrUap\,\rrhUap}

```

20.21.71 Rotations x and xp

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

`\rrhx` 2201 `\newcommand{\rrx}{\@rr{x}}`

`\Rubikx` 2202 `\newcommand{\Rubikx}{\@xyzRubik{x}}`

2203 `\newcommand{\rrhx}{\@xyzh{x}}`

`\rrxp` These commands all draw forms which denote the xp rotation.

`\rrhxp` 2204 `\newcommand{\rrxp}{\@rrp{x}}`

`\Rubikxp` 2205 `\newcommand{\Rubikxp}{\@xyzRubikp{x}}`

2206 `\newcommand{\rrhxp}{\@xyzhp{x}}`

20.21.72 Rotations y and yp

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

`\rrhy` 2207 `\newcommand{\rry}{\@rr{y}}`

`\Rubiky` 2208 `\newcommand{\Rubiky}{\@xyzRubik{y}}`

2209 `\newcommand{\rrhy}{\@xyzh{y}}`

`\rryp` These commands all draw forms which denote the yp rotation.

`\rrhyp` 2210 `\newcommand{\rryp}{\@rrp{y}}`

`\Rubikyp` 2211 `\newcommand{\Rubikyp}{\@xyzRubikp{y}}`

2212 `\newcommand{\rrhyp}{\@xyzhp{y}}`

20.21.73 Rotations z and zp

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

`\rrhz` 2213 `\newcommand{\rrz}{\@rr{z}}`

`\Rubikz` 2214 `\newcommand{\Rubikz}{\@xyzRubik{z}}`

2215 `\newcommand{\rrhz}{\@xyzh{z}}`

`\rrzp` These commands all draw forms which denote the zp rotation.
`\rrhzu` 2216 `\newcommand{\rrzp}{\@rrp{z}}`
`\Rubikzp` 2217 `\newcommand{\Rubikzp}{\@xyzRubikp{z}}`
2218 `\newcommand{\rrhzu}{\@xyzhp{z}}`

20.21.74 Rotations u and d

`\rru` These commands all draw forms which denote the u and up cube rotation.
`\rrhu` 2219 `\newcommand{\rru}{\@rr{u}}`
`\Rubiku` 2220 `\newcommand{\rrup}{\@rrp{u}}`
2221 `\newcommand{\rrhu}{\@xyzh{u}}`
2222 `\newcommand{\rrhup}{\@xyzhp{u}}`
2223 `\newcommand{\Rubiku}{\@xyzRubik{u}}`
2224 `\newcommand{\Rubikup}{\@xyzRubikp{u}}`

`\rrd` These commands all draw forms which denote the d and dp cube rotation.
`\rrhd` 2225 `\newcommand{\rrd}{\@rr{d}}`
`\Rubikd` 2226 `\newcommand{\rrdp}{\@rrp{d}}`
2227 `\newcommand{\rrhd}{\@xyzhbdf1{d}}`
2228 `\newcommand{\rrhdp}{\@xyzhbdf1p{d}}`
2229 `\newcommand{\Rubikd}{\@xyzbdf1Rubik{d}}`
2230 `\newcommand{\Rubikdp}{\@xyzbdf1Rubikp{d}}`

20.21.75 Rotations l and r

`\rrl` These commands all draw forms which denote the l and lp cube rotation.
`\rrhl` 2231 `\newcommand{\rrl}{\@rr{l}}`
`\Rubikl` 2232 `\newcommand{\rrlp}{\@rrp{l}}`
2233 `\newcommand{\rrhl}{\@xyzhbdf1{l}}`
2234 `\newcommand{\rrhlp}{\@xyzhbdf1p{l}}`
2235 `\newcommand{\Rubikl}{\@xyzbdf1Rubik{l}}`
2236 `\newcommand{\Rubiklp}{\@xyzbdf1Rubikp{l}}`

`\rrr` These commands all draw forms which denote the r and rp cube rotation.
`\rrhr` 2237 `\newcommand{\rrr}{\@rr{r}}`
`\Rubikr` 2238 `\newcommand{\rrrp}{\@rrp{r}}`
2239 `\newcommand{\rrhr}{\@xyzh{r}}`
2240 `\newcommand{\rrhrp}{\@xyzhp{r}}`
2241 `\newcommand{\Rubikr}{\@xyzRubik{r}}`
2242 `\newcommand{\Rubikrp}{\@xyzRubikp{r}}`

20.21.76 Rotations f and b

`\rrf` These commands all draw forms which denote the f and fp cube rotation.
`\rrhf` 2243 `\newcommand{\rrf}{\@rr{f}}`
`\Rubikf` 2244 `\newcommand{\rrfp}{\@rrp{f}}`
2245 `\newcommand{\rrhf}{\@xyzhbdf1{f}}`
2246 `\newcommand{\rrhfp}{\@xyzhbdf1p{f}}`

```
2247 \newcommand{\Rubikf}{\@xyzbdf1Rubik{f}}
2248 \newcommand{\Rubikfp}{\@xyzbdf1Rubikp{f}}
```

`\rrb` These commands all draw forms which denote the b and bp cube rotation.

```
\rrhb 2249 \newcommand{\rrb}{\@rr{b}}
\Rubikb 2250 \newcommand{\rrbp}{\@rrp{b}}
2251 \newcommand{\rrhb}{\@xyzhbdf1{b}}
2252 \newcommand{\rrhbp}{\@xyzhbdf1p{b}}
2253 \newcommand{\Rubikb}{\@xyzbdf1Rubik{b}}
2254 \newcommand{\Rubikbp}{\@xyzbdf1Rubikp{b}}
```

20.22 Face(c) and Face(m) rotations

This subsection (added Nov 2016) is to accommodate some additional notation, much used on the Jaap Puzzles website (Scherphius J), which, although quite convenient, is technically ‘non-standard’. This additional notation makes available the (middle slice) rotations of the form Rm, Rmp, Lm, Lmp, ... and also the (whole cube) rotations Rc, Lc, ... (referenced to a face) as used on the Cube Lovers usenet group (1981–1997). This notation was probably invented by Singmaster (see Scherphius J).

```
\@xyzhc First we have some useful facilitating commands we shall make use of in conjunc-
\@xyzhcp tion with the Face(c) and Face(cp) notation.
\@xyzRubikc 2255 \newcommand{\@xyzhc}[1]{\raisebox{-1.2pt}%
\@xyzRubikcp 2256 {\@rubikfont #1\@rubikfontFNS c}}
2257 \newcommand{\@xyzhcp}[1]{\raisebox{-1.2pt}%
2258 {\@rubikfont #1\@rubikfontFNS c}\@rubikprime}}
2259 \newcommand{\@xyzRubikc}[1]{\raisebox{3.45pt}%
2260 {\raisebox{-1.2pt}{\@rubikfont #1\@rubikfontFNS c}}}}
2261 \newcommand{\@xyzRubikcp}[1]{\raisebox{3.45pt}%
2262 {\raisebox{-1.2pt}{\@rubikfont #1\@rubikfontFNS c}\@rubikprime}}}}
```

20.22.1 Rotations Rc and Rcp

Whole cube rotations Rc = x, Rcp = xp.

```
\rrRc These commands all draw forms which denote the Rc rotation.
\rrhRc 2263 \newcommand{\rrRc}{\@rrc{R}}
\RubikRc 2264 \newcommand{\RubikRc}{\@xyzRubikc{R}}
2265 \newcommand{\rrhRc}{\@xyzhc{R}}
```

```
\rrRcp These commands all draw forms which denote the Rcp rotation.
\rrhRcp 2266 \newcommand{\rrRcp}{\@rrcp{R}}
\RubikRcp 2267 \newcommand{\RubikRcp}{\@xyzRubikcp{R}}
2268 \newcommand{\rrhRcp}{\@xyzhcp{R}}
```

20.22.2 Rotations Lc and Lcp

Whole cube rotations $Lc = xp$, $Lcp = x$.

`\rrLc` These commands all draw forms which denote the Lc rotation.
`\rrhLc` 2269 `\newcommand{\rrLc}{\@rrc{L}}`
`\RubikLc` 2270 `\newcommand{\RubikLc}{\@xyzRubikc{L}}`
2271 `\newcommand{\rrhLc}{\@xyzhc{L}}`

`\rrLcp` These commands all draw forms which denote the Lcp rotation.
`\rrhLcp` 2272 `\newcommand{\rrLcp}{\@rrcp{L}}`
`\RubikLcp` 2273 `\newcommand{\RubikLcp}{\@xyzRubikcp{L}}`
2274 `\newcommand{\rrhLcp}{\@xyzhcp{L}}`

20.22.3 Rotations Uc and Ucp

Whole cube rotation $Uc = y$, $Ucp = yp$.

`\rrUc` These commands all draw forms which denote the Uc rotation.
`\rrhUc` 2275 `\newcommand{\rrUc}{\@rrc{U}}`
`\RubikUc` 2276 `\newcommand{\RubikUc}{\@xyzRubikc{U}}`
2277 `\newcommand{\rrhUc}{\@xyzhc{U}}`

`\rrUcp` These commands all draw forms which denote the Ucp rotation.
`\rrhUcp` 2278 `\newcommand{\rrUcp}{\@rrcp{U}}`
`\RubikUcp` 2279 `\newcommand{\RubikUcp}{\@xyzRubikcp{U}}`
2280 `\newcommand{\rrhUcp}{\@xyzhcp{U}}`

20.22.4 Rotations Dc and Dcp

Whole cube rotations $Dc = yp$, $Dcp = y$.

`\rrDc` These commands all draw forms which denote the Dc rotation.
`\rrhDc` 2281 `\newcommand{\rrDc}{\@rrc{D}}`
`\RubikDc` 2282 `\newcommand{\RubikDc}{\@xyzRubikc{D}}`
2283 `\newcommand{\rrhDc}{\@xyzhc{D}}`

`\rrDcp` These commands all draw forms which denote the Dcp rotation.
`\rrhDcp` 2284 `\newcommand{\rrDcp}{\@rrcp{D}}`
`\RubikDcp` 2285 `\newcommand{\RubikDcp}{\@xyzRubikcp{D}}`
2286 `\newcommand{\rrhDcp}{\@xyzhcp{D}}`

20.22.5 Rotations Fc and Fcp

Whole cube rotations $Fc = z$, $Fcp = zp$.

`\rrFc` These commands all draw forms which denote the Fc rotation.
`\rrhFc` 2287 `\newcommand{\rrFc}{\@rrc{F}}`
`\RubikFc` 2288 `\newcommand{\RubikFc}{\@xyzRubikc{F}}`
2289 `\newcommand{\rrhFc}{\@xyzhc{F}}`

`\rrFcp` These commands all draw forms which denote the Fcp rotation.
`\rrhFcp` 2290 `\newcommand{\rrFcp}{\@rrcp{F}}`
`\RubikFcp` 2291 `\newcommand{\RubikFcp}{\@xyzRubikcp{F}}`
2292 `\newcommand{\rrhFcp}{\@xyzhcp{F}}`

20.22.6 Rotations Bc and Bcp

Whole cube rotation Bc = zp, Bcp = z.

`\rrBc` These commands all draw forms which denote the Bc rotation.
`\rrhBc` 2293 `\newcommand{\rrBc}{\@rrc{B}}`
`\RubikBc` 2294 `\newcommand{\RubikBc}{\@xyzRubikc{B}}`
2295 `\newcommand{\rrhBc}{\@xyzhc{B}}`

`\rrBcp` These commands all draw forms which denote the Bcp rotation.
`\rrhBcp` 2296 `\newcommand{\rrBcp}{\@rrcp{B}}`
`\RubikBcp` 2297 `\newcommand{\RubikBcp}{\@xyzRubikcp{B}}`
2298 `\newcommand{\rrhBcp}{\@xyzhcp{B}}`

20.22.7 Rotations Rm and Rmp

Rm = Mp= Sr (M follows Left). We use Sr and Srp as the templates.

`\rrRm` These commands draw forms of the Rm slice rotation.
`\rrhRm` 2299 `\newcommand{\rrRm}{\@rrm{R}}`
`\RubikRm` 2300 `\newcommand{\rrhRm}{\rrhMp}%`
`\textRubikRm` 2301 `\newcommand{\RubikRm}{%`
2302 `{\@rubikfont%`
2303 `\begin{minipage}{0.6cm}`
2304 `\centering%`
2305 `\SquareMp\`
2306 `\rrRm%`
2307 `\end{minipage}%`
2308 `}}`
2309 `\newcommand{\textRubikRm}{\rrRm\,\rrhMp}`

`\rrRmp` These commands draw forms of the Rmp slice rotation.
`\rrhRmp` 2310 `\newcommand{\rrRmp}{\@rrmp{R}}`
`\RubikRmp` 2311 `\newcommand{\rrhRmp}{\rrhM}%`
`\textRubikRmp` 2312 `\newcommand{\RubikRmp}{%`
2313 `{\@rubikfont%`
2314 `\begin{minipage}{0.6cm}`
2315 `\centering%`
2316 `\SquareM\`
2317 `\rrRmp%`
2318 `\end{minipage}%`
2319 `}}`
2320 `\newcommand{\textRubikRmp}{\rrRmp\,\rrhM}`

20.22.8 Rotations Lm and Lmp

$Lm = M = Sl$ (M follows $Left$). We use Sl and Slp as the templates.

```

\rrLm These commands draw forms of the Lm slice rotation.
\rrhLm 2321 \newcommand{\rrLm}{\@rrm{L}}
\RubikLm 2322 \newcommand{\rrhLm}{\rrhM}%
\textRubikLm 2323 \newcommand{\RubikLm}{%
2324 {\@rubikfont%
2325 \begin{minipage}{0.6cm}
2326 \centering%
2327 \SquareM\\
2328 \rrLm%
2329 \end{minipage}%
2330 }}
2331 \newcommand{\textRubikLm}{\rrLm\,\rrhM}

\rrLmp These commands draw forms of the Lmp slice rotation.
\rrhLmp 2332 \newcommand{\rrLmp}{\@rrmp{L}}
\RubikLmp 2333 \newcommand{\rrhLmp}{\rrhMp}%
\textRubikLmp 2334 \newcommand{\RubikLmp}{%
2335 {\@rubikfont%
2336 \begin{minipage}{0.6cm}
2337 \centering%
2338 \SquareMp\\
2339 \rrLmp%
2340 \end{minipage}%
2341 }}
2342 \newcommand{\textRubikLmp}{\rrLmp\,\rrhMp}

```

20.22.9 Rotations Um and Ump

$Um = Ep = Su$ (E follows $Down$). We use Su and Sup as the templates.

```

\rrUm These commands draw forms of the Um slice rotation. We also need to fine-tune
\rrhUm the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
\RubikUm 2343 \newcommand{\rrUm}{\@rrm{U}}
\textRubikUm 2344 \newcommand{\rrhUm}{\rrhEp}%
2345 \newcommand{\RubikUm}{%
2346 {\@rubikfont%
2347 \begin{minipage}{0.6cm}
2348 \centering%
2349 \SquareEp\\
2350 \rrUm%
2351 \end{minipage}%
2352 }}
2353 \newcommand{\textRubikUm}{\rrUm\,\rrhEp}

\rrUmp These commands draw forms of the Ump slice rotation. We also need to fine-tune
\rrhUmp the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
\RubikUmp
\textRubikUmp

```

```

2354 \newcommand{\rrUmp}{\@rrmp{U}}
2355 \newcommand{\rrhUmp}{\rrhE}%
2356 \newcommand{\RubikUmp}{%
2357 {\@rubikfont%
2358 \begin{minipage}{0.6cm}
2359 \centering%
2360 \SquareE\\
2361 \rrUmp%
2362 \end{minipage}%
2363 }}
2364 \newcommand{\textRubikUmp}{\rrUmp\,\rrhE}

```

20.22.10 Rotations Dm and Dmp

Dm = E = Sd (E follows Down). We use Sd and Sdp as the templates.

```

\rrDm These commands draw forms of the Singmaster Dm slice rotation.
\rrhDm
\RubikDm
\textRubikDm
2365 \newcommand{\rrDm}{\@rrm{D}}
2366 \newcommand{\rrhDm}{\rrhE}%
2367 \newcommand{\RubikDm}{%
2368 {\@rubikfont%
2369 \begin{minipage}{0.6cm}
2370 \centering%
2371 \SquareE\\
2372 \rrDm%
2373 \end{minipage}%
2374 }}
2375 \newcommand{\textRubikDm}{\rrDm\,\rrhE}

```

```

\rrDmp These commands draw forms of the Singmaster Dmp slice rotation.
\rrhDmp
\RubikDmp
\textRubikDmp
2376 \newcommand{\rrDmp}{\@rrmp{D}}
2377 \newcommand{\rrhDmp}{\rrhEp}%
2378 \newcommand{\RubikDmp}{%
2379 {\@rubikfont%
2380 \begin{minipage}{0.6cm}
2381 \centering%
2382 \SquareEp\\
2383 \rrDmp%
2384 \end{minipage}%
2385 }}
2386 \newcommand{\textRubikDmp}{\rrDmp\,\rrhEp}

```

20.22.11 Rotations Fm and Fmp

Fm = S = Sf (S follows Front). S is not visible from the front, so is represented in a square box. We use Sf and Sfp as the templates.

```

\rrFm These commands draw forms of the Fm slice rotation. We need to just make
\rrhFm square with Fm in square; adjust box height using a \rule; adjust \fboxsep
\RubikFm
\textRubikFm

```

(default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to reset to defaults. Not visible from the front.

```
2387 \newcommand{\rrFm}{\@rrm{F}}
2388 \newcommand{\SquareFm}{\@tlen\@SquareLetter{\rrFm}\@tlen}
2389 \newcommand{\rrhFm}{\raisebox{-0.25mm}{\SquareFm}}
2390 \newcommand{\RubikFm}{\raisebox{\@hRubik}{\SquareFm}}
2391 \newcommand{\textRubikFm}{\rrhFm}
```

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

```
2392 \newcommand{\rrFmp}{\@rrmp{F}}
2393 \newcommand{\SquareFmp}{\@tlen\@SquareLetter{\rrFmp}\@tlen}
2394 \newcommand{\rrhFmp}{\raisebox{-0.25mm}{\SquareFmp}}
2395 \newcommand{\RubikFmp}{\raisebox{\@hRubik}{\SquareFmp}}
2396 \newcommand{\textRubikFmp}{\rrhFmp}
```

20.22.12 Rotations Bm and Bmp

Bm = Sp = Sb. We use Sb and Sbp as the templates.

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

```
2397 \newcommand{\rrBm}{\@rrm{B}}
2398 \newcommand{\SquareBm}{\@tlen\@SquareLetter{\rrBm}\@tlen}
2399 \newcommand{\rrhBm}{\raisebox{-0.25mm}{\SquareBm}}
2400 \newcommand{\RubikBm}{\raisebox{\@hRubik}{\SquareBm}}
2401 \newcommand{\textRubikBm}{\rrhBm}
```

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

```
2402 \newcommand{\rrBmp}{\@rrmp{B}}
2403 \newcommand{\SquareBmp}{\@tlen\@SquareLetter{\rrBmp}\@tlen}
2404 \newcommand{\rrhBmp}{\raisebox{-0.25mm}{\SquareBmp}}
2405 \newcommand{\RubikBmp}{\raisebox{\@hRubik}{\SquareBmp}}
2406 \newcommand{\textRubikBmp}{\rrhBmp}
```

20.23 Randelshofer superset ENG rotations (CMST)

(see webpage: Randelshofer.ch/rubik/patterns/doc/supersetENG_3x3.html)

This section relates to the recent Rubik notation developed by Randelshofer (see URL above), known as the “superset ENG rotations” (see Sections 9 and 9.9.1 for details).

I denote this notation as “CMST” (i.e., his C, M, S and T notation). Although this notation replicates previously existing World Cube Association notation, we include it here for completeness. Fortunately the Randelshofer notation does not conflict with existing notation.

Briefly, the CMST letters denote whole Cube, Middle, outer-Slice and wide (T) rotations associated with named faces. For example, the rotation-code MR indicates a rotation of the middle slice parallel to the RIGHT face, and in the same sense (direction) as **R** (see Section 9 for details).

First we make some useful facilitating commands for the CX1 and CX1p forms as these are handled with raised square brackets. We model these four macros on the equivalent `\@xyzh`, `\@xyzhp`, `\@xyzRubik`, `\@xyzRubikp` macros defined above.

```
2407 \newcommand{\@randhc}[1]{[\raisebox{-1.2pt}{\@rubikfont C#1}]}
2408 \newcommand{\@randhcp}[1]{[\raisebox{-1.2pt}{\@rubikfont C#1\@rubikprime}]}
2409 \newcommand{\@randRubikc}[1]{
2410   {\raisebox{3.45pt}{[\raisebox{-1.2pt}{\@rubikfont C#1}]}]}
2411 \newcommand{\@randRubikcp}[1]{
2412   {\raisebox{3.45pt}{[\raisebox{-1.2pt}{\@rubikfont C#1\@rubikprime}]}]}
```

In the following we create the base form of a rotation code, eg **[CR]** and then the user typesets this rotation using CR as the argument for `\rrh{}`. This works because the macro `\@join{}` is used to join `\rrh` and `CR` \rightarrow `\rrhCR` etc.

The = signs at the beginning of each new section indicate the equivalence between the Randelshofer notation and the current (World Cube Association) notation.

20.23.1 Rotations CR and CRp

Whole cube rotations $CR = Rc = x$, $CRp = Rcp = xp$.

`\rrCR` These commands all draw forms which denote the $CR = Rc$ rotation.
`\rrhCR` 2413 `\newcommand{\rrCR}{\@rr{CR}}`
`\RubikCR` 2414 `\newcommand{\RubikCR}{\@randRubikc{R}}`
 2415 `\newcommand{\rrhCR}{\@randhc{R}}`

`\rrCRp` These commands all draw forms which denote the $CRp = Rcp$ rotation.
`\rrhCRp` 2416 `\newcommand{\rrCRp}{\@rrp{CR}}`
`\RubikCRp` 2417 `\newcommand{\RubikCRp}{\@randRubikcp{R}}`
 2418 `\newcommand{\rrhCRp}{\@randhcp{R}}`

20.23.2 Rotations CL and CLp

Whole cube rotations $CL = Lc = xp$, $CLp = Lcp = x$.

`\rrCL` These commands all draw forms which denote the CL rotation.
`\rrhCL` 2419 `\newcommand{\rrCL}{\@rr{CL}}`
`\RubikCL` 2420 `\newcommand{\RubikCL}{\@randRubikc{L}}`
 2421 `\newcommand{\rrhCL}{\@randhc{L}}`

`\rrCLp` These commands all draw forms which denote the CLp rotation.
`\rrhCLp` 2422 `\newcommand{\rrCLp}{\@rrp{CL}}`
`\RubikCLp` 2423 `\newcommand{\RubikCLp}{\@randRubikcp{L}}`
2424 `\newcommand{\rrhCLp}{\@randhcp{L}}`

20.23.3 Rotations CU and CUp

Whole cube rotation $CU = Uc = y$, $CUp = Ucp = yp$.

`\rrCU` These commands all draw forms which denote the CU rotation.
`\rrhCU` 2425 `\newcommand{\rrCU}{\@rr{CU}}`
`\RubikCU` 2426 `\newcommand{\RubikCU}{\@randRubikc{U}}`
2427 `\newcommand{\rrhCU}{\@randhc{U}}`

`\rrCUp` These commands all draw forms which denote the CUp rotation.
`\rrhCUp` 2428 `\newcommand{\rrCUp}{\@rrp{CU}}`
`\RubikCUp` 2429 `\newcommand{\RubikCUp}{\@randRubikcp{U}}`
2430 `\newcommand{\rrhCUp}{\@randhcp{U}}`

20.23.4 Rotations CD and CDp

Whole cube rotations $CD = Dc = yp$, $CDp = Dcp = y$.

`\rrCD` These commands all draw forms which denote the CD rotation.
`\rrhCD` 2431 `\newcommand{\rrCD}{\@rr{CD}}`
`\RubikCD` 2432 `\newcommand{\RubikCD}{\@randRubikc{D}}`
2433 `\newcommand{\rrhCD}{\@randhc{D}}`

`\rrCDp` These commands all draw forms which denote the CDp rotation.
`\rrhCDp` 2434 `\newcommand{\rrCDp}{\@rrp{CD}}`
`\RubikCDp` 2435 `\newcommand{\RubikCDp}{\@randRubikcp{D}}`
2436 `\newcommand{\rrhCDp}{\@randhcp{D}}`

20.23.5 Rotations CF and CFp

Whole cube rotations $CF = Fc = z$, $CFp = Fcp = zp$.

`\rrCF` These commands all draw forms which denote the CF rotation.
`\rrhCF` 2437 `\newcommand{\rrCF}{\@rr{CF}}`
`\RubikCF` 2438 `\newcommand{\RubikCF}{\@randRubikc{F}}`
2439 `\newcommand{\rrhCF}{\@randhc{F}}`

`\rrCFp` These commands all draw forms which denote the CFp rotation.
`\rrhCFp` 2440 `\newcommand{\rrCFp}{\@rrp{CF}}`
`\RubikCFp` 2441 `\newcommand{\RubikCFp}{\@randRubikcp{F}}`
2442 `\newcommand{\rrhCFp}{\@randhcp{F}}`

20.23.6 Rotations CB and CBp

Whole cube rotation $CB = Bc = zp$, $CBp = Bcp = z$.

`\rrCB` These commands all draw forms which denote the CB rotation.
`\rrhCB` 2443 `\newcommand{\rrCB}{\@rr{CB}}`
`\RubikCB` 2444 `\newcommand{\RubikCB}{\@randRubikc{B}}`
2445 `\newcommand{\rrhCB}{\@randhc{B}}`

`\rrCBp` These commands all draw forms which denote the CBp rotation.
`\rrhCBp` 2446 `\newcommand{\rrCBp}{\@rrp{CB}}`
`\RubikCBp` 2447 `\newcommand{\RubikCBp}{\@randRubikcp{B}}`
2448 `\newcommand{\rrhCBp}{\@randhcp{B}}`

20.23.7 Rotations MR and MRp

$MR = Rm = Mp = Sr$ (M follows Left). We use Sr and Srp as the templates.

`\rrMR` These commands draw forms of the MR middle slice rotation.
`\rrhMR` 2449 `\newcommand{\rrMR}{\@rr{MR}}`
`\RubikMR` 2450 `\newcommand{\rrhMR}{\rrhMp}%`
`\textRubikMR` 2451 `\newcommand{\RubikMR}{%`
2452 `{\@rubikfont%`
2453 `\begin{minipage}{0.6cm}`
2454 `\centering%`
2455 `\SquareMp\`
2456 `\rrMR%`
2457 `\end{minipage}%`
2458 `}}`
2459 `\newcommand{\textRubikMR}{\rrMR\,\rrhMp}`

`\rrMRp` These commands draw forms of the MRp slice rotation.
`\rrhMRp` 2460 `\newcommand{\rrMRp}{\@rrp{MR}}`
`\RubikMRp` 2461 `\newcommand{\rrhMRp}{\rrhM}%`
`\textRubikMRp` 2462 `\newcommand{\RubikMRp}{%`
2463 `{\@rubikfont%`
2464 `\begin{minipage}{0.6cm}`
2465 `\centering%`
2466 `\SquareM\`
2467 `\rrMRp%`
2468 `\end{minipage}%`
2469 `}}`
2470 `\newcommand{\textRubikMRp}{\rrMRp\,\rrhM}`

20.23.8 Rotations ML and MLp

$ML = Lm = M = Sl$ (M follows Left). We use Sl and Slp as the templates.

`\rrML` These commands draw forms of the ML slice rotation.

`\rrhML` 2471 `\newcommand{\rrML}{\@rr{ML}}`

`\RubikML` 2472 `\newcommand{\rrhML}{\rrhM}%`

`\textRubikML` 2473 `\newcommand{\RubikML}{%`
2474 `{\@rubikfont%`
2475 `\begin{minipage}{0.6cm}`
2476 `\centering%`
2477 `\SquareM\`
2478 `\rrML%`
2479 `\end{minipage}%`
2480 `}`
2481 `\newcommand{\textRubikML}{\rrML\,\rrhM}`

`\rrMLp` These commands draw forms of the MLp slice rotation.

`\rrhMLp` 2482 `\newcommand{\rrMLp}{\@rrp{ML}}`

`\RubikMLp` 2483 `\newcommand{\rrhMLp}{\rrhMp}%`

`\textRubikMLp` 2484 `\newcommand{\RubikMLp}{%`
2485 `{\@rubikfont%`
2486 `\begin{minipage}{0.6cm}`
2487 `\centering%`
2488 `\SquareMp\`
2489 `\rrMLp%`
2490 `\end{minipage}%`
2491 `}`
2492 `\newcommand{\textRubikMLp}{\rrMLp\,\rrhMp}`

20.23.9 Rotations MU and MUp

MU = Um = Ep = Su (E follows Down). We use Su and Sup as the templates.

`\rrMU` These commands draw forms of the MU slice rotation.

`\rrhMU` 2493 `\newcommand{\rrMU}{\@rr{MU}}`

`\RubikMU` 2494 `\newcommand{\rrhMU}{\rrhEp}%`

`\textRubikMU` 2495 `\newcommand{\RubikMU}{%`
2496 `{\@rubikfont%`
2497 `\begin{minipage}{0.6cm}`
2498 `\centering%`
2499 `\SquareEp\`
2500 `\rrMU%`
2501 `\end{minipage}%`
2502 `}`
2503 `\newcommand{\textRubikMU}{\rrMU\,\rrhEp}`

`\rrMUp` These commands draw forms of the MUp slice rotation.

`\rrhMUp` 2504 `\newcommand{\rrMUp}{\@rrp{MU}}`

`\RubikMUp` 2505 `\newcommand{\rrhMUp}{\rrhE}%`

`\textRubikMUp` 2506 `\newcommand{\RubikMUp}{%`
2507 `{\@rubikfont%`
2508 `\begin{minipage}{0.6cm}`


```

2509 \centering%
2510 \SquareE\
2511 \rrMU%
2512 \end{minipage}%
2513 }}
2514 \newcommand{\textRubikMU}{\rrMU\,\rrhE}

```

20.23.10 Rotations MD and MDp

MD = Dm = E = Sd (E follows Down). We use Sd and Sdp as the templates.

```

\rrMD These commands draw forms of the Randelshofer MD slice rotation.
\rrhMD
\RubikMD
\textRubikMD
2515 \newcommand{\rrMD}{\@rr{MD}}
2516 \newcommand{\rrhMD}{\rrhE}%
2517 \newcommand{\RubikMD}{%
2518 {\@rubikfont%
2519 \begin{minipage}{0.6cm}
2520 \centering%
2521 \SquareE\
2522 \rrMD%
2523 \end{minipage}%
2524 }}
2525 \newcommand{\textRubikMD}{\rrMD\,\rrhE}

```

```

\rrMDp These commands draw forms of the Randelshofer MDp slice rotation.
\rrhMDp
\RubikMDp
\textRubikMDp
2526 \newcommand{\rrMDp}{\@rrp{MD}}
2527 \newcommand{\rrhMDp}{\rrhEp}%
2528 \newcommand{\RubikMDp}{%
2529 {\@rubikfont%
2530 \begin{minipage}{0.6cm}
2531 \centering%
2532 \SquareEp\
2533 \rrMDp%
2534 \end{minipage}%
2535 }}
2536 \newcommand{\textRubikMDp}{\rrMDp\,\rrhEp}

```

20.23.11 Rotations MF and MFp

MF = Fm = S = Sf (S follows Front). MF = S is not visible from the front, so is represented in a square box. We use Sf and Sfp as the templates.

```

\rrMF These commands draw forms of the MF slice rotation. We need to just make
\rrhMF square with MF in square; adjust box height using a \rule; adjust \fboxsep
\RubikMF (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikMF reset to defaults. Not visible from the front.
2537 \newcommand{\rrMF}{\@rr{MF}}
2538 \newcommand{\SquareMF}{\@tlen\@SquareLetter{\rrMF}\@tlen}
2539 \newcommand{\rrhMF}{\raisebox{-0.25mm}{\SquareMF}}

```

```

2540 \newcommand{\RubikMF}{\raisebox{\@hRubik}{\SquareMF}}
2541 \newcommand{\textRubikMF}{\rrhMF}

```

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

```

2542 \newcommand{\rrMFp}{\@rrp{MF}}
2543 \newcommand{\SquareMFp}{\@tlen\@SquareLetter{\rrMFp}\@tlen}
2544 \newcommand{\rrhMFp}{\raisebox{-0.25mm}{\SquareMFp}}
2545 \newcommand{\RubikMFp}{\raisebox{\@hRubik}{\SquareMFp}}
2546 \newcommand{\textRubikMFp}{\rrhMFp}

```

20.23.12 Rotations MB and MBp

MB = Bm = Sp = Sb. We use Sb and Sbp as the templates.

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

```

2547 \newcommand{\rrMB}{\@rrp{MB}}
2548 \newcommand{\SquareMB}{\@tlen\@SquareLetter{\rrMB}\@tlen}
2549 \newcommand{\rrhMB}{\raisebox{-0.25mm}{\SquareMB}}
2550 \newcommand{\RubikMB}{\raisebox{\@hRubik}{\SquareMB}}
2551 \newcommand{\textRubikMB}{\rrhMB}

```

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

```

2552 \newcommand{\rrMBp}{\@rrp{MBp}}
2553 \newcommand{\SquareMBp}{\@tlen\@SquareLetter{\rrMBp}\@tlen}
2554 \newcommand{\rrhMBp}{\raisebox{-0.25mm}{\SquareMBp}}
2555 \newcommand{\RubikMBp}{\raisebox{\@hRubik}{\SquareMBp}}
2556 \newcommand{\textRubikMBp}{\rrhMBp}

```

20.23.13 Rotations T (wide)

TR = Rw (We use Rw and Rwp as the templates).

We first set up some useful T and Tp macros for use with (L,R,U,D,F,B) slightly more general than before. As before the rubikfont command needs to be delimited using two curly brackets to contain the font expression.

```

2557 \newcommand{\@rrT}[1]{\@rubikfont T#1}
2558 \newcommand{\@rrhT}[1]{\@join{\rrh#1}{w}}
2559 \newcommand{\@textRubikT}[1]{\@rrT{#1}\,\@join{\rrh#1}{w}}
2560 %
2561 \newcommand{\@RubikT}[1]{%

```

```

2562 {\@rubikfont%
2563 \begin{minipage}{0.6cm}
2564 \centering%%
2565 \@join{\Square#1}{w}\%
2566 \@rrT{#1}%%
2567 \end{minipage}%
2568 }}
2569 %%
2570 \newcommand{\@rrTp}[1]{\@rubikfont T#1\@rubikprime}}
2571 \newcommand{\@rrhTp}[1]{\@join{\rrh#1}{wp}}%
2572 \newcommand{\@textRubikTp}[1]{\@rrTp{#1}\,\@join{\rrh#1}{wp}}
2573 %%
2574 \newcommand{\@RubikTp}[1]{%
2575 {\@rubikfont%
2576 \begin{minipage}{0.6cm}
2577 \centering%%
2578 \@join{\Square#1}{wp}\%
2579 \@rrTp{#1}%%
2580 \end{minipage}%
2581 }}

\rrTL These commands draw forms of the TL = Lw wide slice rotation.
\rrhTL 2582 \newcommand{\rrTL}{\@rrT{L}}% = rrLw
\RubikTL 2583 \newcommand{\rrhTL}{\@rrhT{L}}
\textRubikTL 2584 \newcommand{\textRubikTL}{\@textRubikT{L}}
2585 \newcommand{\RubikTL}{\@RubikT{L}}

\rrTLp These commands draw forms of the TLp = Lwp wide slice rotation.
\rrhTLp 2586 \newcommand{\rrTLp}{\@rrTp{L}}
\RubikTLp 2587 \newcommand{\rrhTLp}{\@rrhTp{L}}
\textRubikTLp 2588 \newcommand{\textRubikTLp}{\@textRubikTp{L}}
2589 \newcommand{\RubikTLp}{\@RubikTp{L}}

\rrTR These commands draw forms of the TR = Rw wide slice rotation.
\rrhTR 2590 \newcommand{\rrTR}{\@rrT{R}}
\RubikTR 2591 \newcommand{\rrhTR}{\@rrhT{R}}
\textRubikTR 2592 \newcommand{\textRubikTR}{\@textRubikT{R}}
2593 \newcommand{\RubikTR}{\@RubikT{R}}

\rrTRp These commands draw forms of the TRp = Rmp wide slice rotation.
\rrhTRp 2594 \newcommand{\rrTRp}{\@rrTp{R}}
\RubikTRp 2595 \newcommand{\rrhTRp}{\@rrhTp{R}}
\textRubikTRp 2596 \newcommand{\textRubikTRp}{\@textRubikTp{R}}
2597 \newcommand{\RubikTRp}{\@RubikTp{R}}

\rrTU These commands draw forms of the TU = Uw wide slice rotation.
\rrhTU 2598 \newcommand{\rrTU}{\@rrT{U}}
\RubikTU 2599 \newcommand{\rrhTU}{\@rrhT{U}}
\textRubikTU 2600 \newcommand{\textRubikTU}{\@textRubikT{U}}
2601 \newcommand{\RubikTU}{\@RubikT{U}}

```

`\rrTUp` These commands draw forms of the TUp = Uwp wide slice rotation.
`\rrhTUp` 2602 `\newcommand{\rrTUp}{\@rrTp{U}}`
`\RubikTUp` 2603 `\newcommand{\rrhTUp}{\@rrhTp{U}}`
`\textRubikTUp` 2604 `\newcommand{\textRubikTUp}{\@textRubikTp{U}}`
2605 `\newcommand{\RubikTUp}{\@RubikTp{U}}`

`\rrTD` These commands draw forms of the TD = Dw wide slice rotation.
`\rrhTD` 2606 `\newcommand{\rrTD}{\@rrT{D}}`
`\RubikTD` 2607 `\newcommand{\rrhTD}{\@rrhT{D}}`
`\textRubikTD` 2608 `\newcommand{\textRubikTD}{\@textRubikT{D}}`
2609 `\newcommand{\RubikTD}{\@RubikT{D}}`

`\rrTDp` These commands draw forms of the TDp = Dwp wide slice rotation.
`\rrhTDp` 2610 `\newcommand{\rrTDp}{\@rrTp{D}}`
`\RubikTDp` 2611 `\newcommand{\rrhTDp}{\@rrhTp{D}}`
`\textRubikTDp` 2612 `\newcommand{\textRubikTDp}{\@textRubikTp{D}}`
2613 `\newcommand{\RubikTDp}{\@RubikTp{D}}`

`\rrTF` These commands draw forms of the TF = Fw wide slice rotation.
`\rrhTF` 2614 `\newcommand{\rrTF}{\@rrT{F}}`
`\RubikTF` 2615 `\newcommand{\rrhTF}{\@rrhT{F}}`
`\textRubikTF` 2616 `\newcommand{\textRubikTF}{\@textRubikT{F}}`
2617 `\newcommand{\RubikTF}{\@RubikT{F}}`

`\rrTFp` These commands draw forms of the TFp = Fwp wide slice rotation.
`\rrhTFp` 2618 `\newcommand{\rrTFp}{\@rrTp{F}}`
`\RubikTFp` 2619 `\newcommand{\rrhTFp}{\@rrhTp{F}}`
`\textRubikTFp` 2620 `\newcommand{\textRubikTFp}{\@textRubikTp{F}}`
2621 `\newcommand{\RubikTFp}{\@RubikTp{F}}`

`\rrTB` These commands draw forms of the TB = Bw wide slice rotation. NOTE we just
`\rrhTB` use the letters TB in a square
`\RubikTB` 2622 `\newcommand{\rrTB}{\@rrT{B}}`
`\textRubikTB` 2623 `\newcommand{\SquareTB}{\@tlen\@SquareLetter{\rrTB}\@tlen}`
2624 `\newcommand{\rrhTB}{\raisebox{-0.25mm}{\SquareTB}}`
2625 `\newcommand{\textRubikTB}{\rrhTB}`
2626 `\newcommand{\RubikTB}{\raisebox{\@hRubik}{\SquareTB}}`

`\rrTBp` These commands draw forms of the TBp = Bwp wide slice rotation. NOTE we
`\rrhTBp` just use the letters TB' in a square
`\RubikTBp` 2627 `\newcommand{\rrTBp}{\@rrTp{B}}`
`\textRubikTBp` 2628 `\newcommand{\SquareTBp}{\@tlen\@SquareLetter{\rrTBp}\@tlen}`
2629 `\newcommand{\rrhTBp}{\raisebox{-0.25mm}{\SquareTBp}}`
2630 `\newcommand{\textRubikTBp}{\rrhTBp}`
2631 `\newcommand{\RubikTBp}{\raisebox{\@hRubik}{\SquareTBp}}`

20.23.14 Rotations SR and SRp (opposite slices)

opposite slices in same direction $SR = Rs$ (both rotating in R direction)

```

\rrSR These commands draw forms of the SR opposite slice rotation.
\rrhSR 2632 \newcommand{\rrSR}{\@rr{SR}}
\RubikSR 2633 \newcommand{\rrhSR}{\rrhRs}%
\textRubikSR 2634 \newcommand{\RubikSR}{%
2635 {\@rubikfont%
2636 \begin{minipage}{0.6cm}
2637 \centering%
2638 \SquareRs\
2639 \rrSR%
2640 \end{minipage}%
2641 }}
2642 \newcommand{\textRubikSR}{\rrSR\,\rrhRs}

\rrSRp These commands draw forms of the SRp opposite slice rotation.
\rrhSRp 2643 \newcommand{\rrSRp}{\@rrp{SR}}
\RubikSRp 2644 \newcommand{\rrhSRp}{\rrhRsp}%
\textRubikSRp 2645 \newcommand{\RubikSRp}{%
2646 {\@rubikfont%
2647 \begin{minipage}{0.6cm}
2648 \centering%
2649 \SquareRsp\
2650 \rrSRp%
2651 \end{minipage}%
2652 }}
2653 \newcommand{\textRubikSRp}{\rrSRp\,\rrhRsp}

```

20.23.15 Rotations SL and SLp

$SL = Ls$ (both rotating in L direction)

```

\rrSL These commands draw forms of the SL opposite slice rotation.
\rrhSL 2654 \newcommand{\rrSL}{\@rr{SL}}
\RubikSL 2655 \newcommand{\rrhSL}{\rrhLs}%
\textRubikSL 2656 \newcommand{\RubikSL}{%
2657 {\@rubikfont%
2658 \begin{minipage}{0.6cm}
2659 \centering%
2660 \SquareLs\
2661 \rrSL%
2662 \end{minipage}%
2663 }}
2664 \newcommand{\textRubikSL}{\rrSL\,\rrhLs}

\rrSLp These commands draw forms of the SLp opposite slice rotation.
\rrhSLp 2665 \newcommand{\rrSLp}{\@rrp{SL}}
\RubikSLp 2666 \newcommand{\rrhSLp}{\rrhLsp}%
\textRubikSLp

```

```

2667 \newcommand{\RubikSLp}{%
2668 {\@rubikfont%
2669 \begin{minipage}{0.6cm}
2670 \centering%
2671 \SquareLsp\\
2672 \rrSLp%
2673 \end{minipage}%
2674 }}
2675 \newcommand{\textRubikSLp}{\rrSLp\,\rrhLsp}

```

20.23.16 Rotations SU and SUp

SU = Us (both rotating in U direction)

```

\rrSU These commands draw forms of the SU opposite slice rotation.
\rrhSU 2676 \newcommand{\rrSU}{\@rr{SU}}
\RubikSU 2677 \newcommand{\rrhSU}{\rrhUs}%
\textRubikSU 2678 \newcommand{\RubikSU}{%
2679 {\@rubikfont%
2680 \begin{minipage}{0.6cm}
2681 \centering%
2682 \SquareUs\\
2683 \rrSU%
2684 \end{minipage}%
2685 }}
2686 \newcommand{\textRubikSU}{\rrSU\,\rrhUs}

```

```

\rrSUp These commands draw forms of the SUp opposite slice rotation.
\rrhSUp 2687 \newcommand{\rrSUp}{\@rrp{SU}}
\RubikSUp 2688 \newcommand{\rrhSUp}{\rrhUsp}%
\textRubikSUp 2689 \newcommand{\RubikSUp}{%
2690 {\@rubikfont%
2691 \begin{minipage}{0.6cm}
2692 \centering%
2693 \SquareUsp\\
2694 \rrSUp%
2695 \end{minipage}%
2696 }}
2697 \newcommand{\textRubikSUp}{\rrSUp\,\rrhUsp}

```

20.23.17 Rotations SD and SDp

SD = Ds (both rotating in D direction)

```

\rrSD These commands draw forms of the SD opposite slice rotation.
\rrhSD 2698 \newcommand{\rrSD}{\@rr{SD}}
\RubikSD 2699 \newcommand{\rrhSD}{\rrhDs}%
\textRubikSD 2700 \newcommand{\RubikSD}{%
2701 {\@rubikfont%

```

```

2702 \begin{minipage}{0.6cm}
2703 \centering%
2704 \SquareDs\
2705 \rrSD%
2706 \end{minipage}%
2707 }}
2708 \newcommand{\textRubikSD}{\rrSD\,\rrhDs}

\rrSDp These commands draw forms of the SDp opposite slice rotation.
\rrhSDp
\RubikSDp 2709 \newcommand{\rrSDp}{\@rrp{SD}}
\textRubikSDp 2710 \newcommand{\rrhSDp}{\rrhDsp}%
2711 \newcommand{\RubikSDp}{%
2712 {\@rubikfont%
2713 \begin{minipage}{0.6cm}
2714 \centering%
2715 \SquareDsp\
2716 \rrSDp%
2717 \end{minipage}%
2718 }}
2719 \newcommand{\textRubikSDp}{\rrSDp\,\rrhDsp}

```

20.23.18 Rotations SF and SFp

SF = Fs is not visible from the front, so is represented in a square box. Both rotating in the F direction We use Fs and Fsp as the templates.

```

\rrSF These commands draw forms of the SF opposite 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.

2720 \newcommand{\rrSF}{\@rr{SF}}
2721 \newcommand{\SquareSF}{\@tlen\@SquareLetter{\rrSF}\@tlen}
2722 \newcommand{\rrhSF}{\raisebox{-0.25mm}{\SquareSF}}
2723 \newcommand{\RubikSF}{\raisebox{\@hRubik}{\SquareSF}}
2724 \newcommand{\textRubikSF}{\rrhSF}

\rrSFp These commands draw forms of the SFp opposite 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.

2725 \newcommand{\rrSFp}{\@rrp{SF}}
2726 \newcommand{\SquareSFp}{\@tlen\@SquareLetter{\rrSFp}\@tlen}
2727 \newcommand{\rrhSFp}{\raisebox{-0.25mm}{\SquareSFp}}
2728 \newcommand{\RubikSFp}{\raisebox{\@hRubik}{\SquareSFp}}
2729 \newcommand{\textRubikSFp}{\rrhSFp}

```

20.23.19 Rotations SB and SBp

SB = Bs is not visible from the front, so is represented in a square box. Both rotating in the B direction We use Bs and Bsp as the templates.

`\rrSB` These commands draw forms of the SB opposite 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.

```
2730 \newcommand{\rrSB}{\@rr{SB}}
2731 \newcommand{\SquareSB}{\@tlen\@SquareLetter{\rrSB}\@tlen}
2732 \newcommand{\rrhSB}{\raisebox{-0.25mm}{\SquareSB}}
2733 \newcommand{\RubikSB}{\raisebox{\@hRubik}{\SquareSB}}
2734 \newcommand{\textRubikSB}{\rrhSB}
```

`\rrSBp` These commands draw forms of the SBp opposite slice rotation. We need to just
`\rrhSBp` make square with SBp in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikSBp` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikSBp` reset to defaults. Not visible from the front.

```
2735 \newcommand{\rrSBp}{\@rrp{SB}}
2736 \newcommand{\SquareSBp}{\@tlen\@SquareLetter{\rrSBp}\@tlen}
2737 \newcommand{\rrhSBp}{\raisebox{-0.25mm}{\SquareSBp}}
2738 \newcommand{\RubikSBp}{\raisebox{\@hRubik}{\SquareSBp}}
2739 \newcommand{\textRubikSBp}{\rrhSBp}
```

20.24 Axis rotations (textRubik versions)

For completeness we include a `\textRubik` version of all the axis rotation codes (making them equal to their hieroglyphic `\rrh` version). Obviously this list must go at the end of this file. While these commands are perhaps strictly unnecessary, the motivation is to allow users to include them in a `\ShowSequence` command when using the `\textRubik` font argument.

```
2740 \newcommand{\textRubikx}{\rrhx}
2741 \newcommand{\textRubikxp}{\rrhxp}
2742 \newcommand{\textRubiky}{\rrhy}
2743 \newcommand{\textRubikyp}{\rrhyp}
2744 \newcommand{\textRubikz}{\rrhz}
2745 \newcommand{\textRubikzp}{\rrhzp}
2746 \newcommand{\textRubikl}{\rrhl}
2747 \newcommand{\textRubiklp}{\rrhlp}
2748 \newcommand{\textRubikr}{\rrhr}
2749 \newcommand{\textRubikrp}{\rrhrp}
2750 \newcommand{\textRubiku}{\rrhu}
2751 \newcommand{\textRubikup}{\rrhup}
2752 \newcommand{\textRubikd}{\rrhd}
2753 \newcommand{\textRubikdp}{\rrhdp}
2754 \newcommand{\textRubikf}{\rrhf}
2755 \newcommand{\textRubikfp}{\rrhfp}
```



```

2756 \newcommand{\textRubikb}{\rrhb}
2757 \newcommand{\textRubikbp}{\rrhbp}
2758 \newcommand{\textRubikLc}{\rrhLc}
2759 \newcommand{\textRubikLcp}{\rrhLcp}
2760 \newcommand{\textRubikRc}{\rrhRc}
2761 \newcommand{\textRubikRcp}{\rrhRcp}
2762 \newcommand{\textRubikUc}{\rrhUc}
2763 \newcommand{\textRubiUcp}{\rrhUcp}
2764 \newcommand{\textRubikDc}{\rrhDc}
2765 \newcommand{\textRubikDcp}{\rrhDcp}
2766 \newcommand{\textRubikFc}{\rrhFc}
2767 \newcommand{\textRubikFcp}{\rrhFcp}
2768 \newcommand{\textRubikBc}{\rrhBc}
2769 \newcommand{\textRubikBcp}{\rrhBcp}
2770 \newcommand{\textRubikCL}{\rrhCL}
2771 \newcommand{\textRubikCLp}{\rrhCLp}
2772 \newcommand{\textRubikCR}{\rrhCR}
2773 \newcommand{\textRubikCRp}{\rrhCRp}
2774 \newcommand{\textRubikCU}{\rrhCU}
2775 \newcommand{\textRubikCUp}{\rrhCUp}
2776 \newcommand{\textRubikCD}{\rrhCD}
2777 \newcommand{\textRubikCDp}{\rrhCDp}
2778 \newcommand{\textRubikCF}{\rrhCF}
2779 \newcommand{\textRubikCFp}{\rrhCFp}
2780 \newcommand{\textRubikCB}{\rrhCB}
2781 \newcommand{\textRubikCBp}{\rrhCBp}

```

End of this package

```

2782 </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		1701,	1722,	2158,	2179,
\&	.....	73	1743,	1765,	2200,
\,	1244, 1265, 1286,	1786,	1807,	2320,	2331,
	1307, 1328,	1828,	1849,	2342,	2353,
	1349, 1370,	1870,	1891,	2364,	2375,
	1391, 1412,	1912,	1933,	2386,	2459,
	1433, 1452,	1944,	1955,	2470,	2481,
	1471, 1492,	1966,	1977,	2492,	2503,
	1512, 1554,	1988,	1999,	2514,	2525,
	1575, 1596,	2010,	2051,	2536,	2559,
	1617, 1638,	2074,	2095,	2572,	2642,
	1659, 1680,	2116,	2137,	2653,	2664,

2675, 2686,	1181, 1182,	\@rrb	1152, 2021	
2697, 2708, 2719	1183, 2558,	\@rrbp	1153, 2026	
\@RubikT	2559, 2565,	\@rrc	1154, 2263,	
2585, 2593,	2571, 2572, 2578		2269, 2275,	
2601, 2609, 2617	\@randRubikc		2281, 2287, 2293	
\@RubikTp	2409, 2414,	\@rrcp	1155, 2266,	
2589, 2597,	2420, 2426,		2272, 2278,	
2605, 2613, 2621	2432, 2438, 2444		2284, 2290, 2296	
\@SquareLetter	\@randRubikcp	\@rrd	1144, 1945	
... 1134, 1185,	2411, 2417,	\@rrdp	1145, 1956	
1190, 1195,	2423, 2429,	\@rrf	1150, 2011	
1200, 1205,	2435, 2441, 2447	\@rrfp	1151, 2016	
1210, 1215,	\@randhc 2407, 2415,	\@rrhT	2558,	
1220, 1515,	2421, 2427,		2583, 2591,	
1520, 1525,	2433, 2439, 2445		2599, 2607, 2615	
1530, 1914,	\@randhcp 2408, 2418,	\@rrhTp	2571,	
1919, 2012,	2424, 2430,		2587, 2595,	
2017, 2022,	2436, 2442, 2448		2603, 2611, 2619	
2027, 2388,	\@err	1134, 1184,	\@rrl	1146, 1967
2393, 2398,	1224, 1392,		\@rrlp	1147, 1978
2403, 2538,	1434, 1534,		\@rrm	1156, 2299,
2543, 2548,	1702, 1744,			2321, 2343,
2553, 2623,	1913, 2031,			2365, 2387, 2397
2628, 2721,	2201, 2207,		\@rrmp	1157, 2310,
2726, 2731, 2736	2213, 2219,			2332, 2354,
\@gobble	2225, 2231,			2376, 2392, 2402
1179	2237, 2243,	\@rrp	1134, 1189,	
\@hRubik 1134, 1187,	2249, 2413,		1245, 1413,	
1192, 1197,	2419, 2425,		1453, 1555,	
1202, 1207,	2431, 2437,		1723, 1766,	
1212, 1217,	2443, 2449,		1918, 2075,	
1222, 1517,	2471, 2493,		2204, 2210,	
1522, 1527,	2515, 2537,		2216, 2220,	
1532, 1916,	2547, 2632,		2226, 2232,	
1921, 2014,	2654, 2676,		2238, 2244,	
2019, 2024,	2698, 2720, 2730	\@rrT	2250, 2416,	
2029, 2390,			2422, 2428,	
2395, 2400,	\@rrT	2557, 2559,	2434, 2440,	
2405, 2540,		2566, 2582,	2446, 2460,	
2545, 2550,		2590, 2598,	2482, 2504,	
2555, 2626,		2606, 2614, 2622	2526, 2542,	
2631, 2723,	\@rrTp	2570, 2572,	2552, 2643,	
2728, 2733, 2738		2579, 2586,	2665, 2687,	
\@ifpackageloaded .		2594, 2602,	2709, 2725, 2735	
6, 9, 12		2610, 2618, 2627	\@rrr	1148, 1989
\@join 839, 840, 858,	\@rra	1134, 1214,	\@rrrp	1149, 2000
859, 866, 867,		1350, 1524,	\@rrs	1134, 1204,
874, 875, 895,		1660, 1871, 2159		1308, 1514,
896, 920, 921,	\@rrap	1134, 1219,		1618, 1829, 2117
928, 929, 966,		1371, 1529,		
967, 1178, 1180,		1681, 1892, 2180		

\@rrsp . .	<u>1134</u> , 1209,	2151,	2172,	1294,	1313,
	1329, 1519,	2193,	2256,	1314,	1315,
	1639, 1850, 2138	2258,	2260,	1334,	1335,
\@rru	1142, 1923	2262,	2302,	1336,	1355,
\@rrup	1143, 1934	2313,	2324,	1356,	1357,
\@rrw . . .	<u>1134</u> , 1194,	2335,	2346,	1376,	1377,
	1266, 1472,	2357,	2368,	1378,	1397,
	1576, 1787, 2052	2379,	2407,	1398,	1399,
\@rrwp . .	<u>1134</u> , 1199,	2408,	2410,	1418,	1419,
	1287, 1493,	2412,	2452,	1420,	1539,
	1597, 1808, 2096	2463,	2474,	1540,	1541,
\@rubikfont	<u>24</u> , 1134,	2485,	2496,	1560,	1561,
	1135, 1136,	2507,	2518,	1562,	1581,
	1137, 1138,	2529,	2557,	1582,	1583,
	1139, 1140,	2562,	2570,	1602,	1603,
	1141, 1142,	2575,	2635,	1604,	1623,
	1143, 1144,	2646,	2657,	1624,	1625,
	1145, 1146,	2668,	2679,	1644,	1645,
	1147, 1148,	2690, 2701, 2712		1646,	1665,
	1149, 1150,	\@rubikfontFNS		1666,	1667,
	1151, 1152,	. . . . <u>24</u> , 1136,		1686,	1687,
	1153, 1154,	1137, 1138,		1688,	1707,
	1155, 1156,	1139, 1140,		1708,	1709,
	1157, 1158,	1141, 1142,		1728,	1729,
	1159, 1161,	1143, 1144,		1730,	1750,
	1163, 1165,	1145, 1146,		1751,	1752,
	1167, 1169,	1147, 1148,		1771,	1772,
	1171, 1237,	1149, 1150,		1773,	1792,
	1258, 1279,	1151, 1152,		1793,	1794,
	1300, 1321,	1153, 1154,		1813,	1814,
	1342, 1363,	1155, 1156,		1815,	1834,
	1384, 1405,	1157, 2256,		1835,	1836,
	1426, 1445,	2258, 2260, 2262		1855,	1856,
	1464, 1485,	\@rubikprime . . . <u>24</u> ,		1857,	1876,
	1505, 1547,	1135, 1137,		1877,	1878,
	1568, 1589,	1139, 1141,		1897,	1898,
	1610, 1631,	1143, 1145,		1899,	2036,
	1652, 1673,	1147, 1149,		2037,	2038,
	1694, 1715,	1151, 1153,		2057,	2058,
	1736, 1758,	1155, 1157,		2059,	2080,
	1779, 1800,	1159, 1163,		2081,	2082,
	1821, 1842,	1167, 1171,		2101,	2102,
	1863, 1884,	2258, 2262,		2103,	2122,
	1905, 1926,	2408, 2412, 2570		2123,	2124,
	1937, 1948,	\@sb 1128, 1129, 1229,		2143,	2144,
	1959, 1970,	1230, 1231,		2145,	2164,
	1981, 1992,	1250, 1251,		2165,	2166,
	2003, 2044,	1252, 1271,		2185, 2186, 2187	
	2066, 2088,	1272, 1273,	\@sbh . . .	1129, 1229,	
	2109, 2130,	1292, 1293,		1230, 1231,	

1250,	1251,	2165,	2166,	1604,	1625,
1252,	1271,	2185,	2186, 2187	1646,	1667,
1272,	1273,	\@scx	1130, 1132, 1439,	1688,	1709,
1292,	1293,		1458, 1477, 1498	1730,	1752,
1294,	1313,	\@scy	1131, 1133, 1439,	1773,	1794,
1314,	1315,		1458, 1477, 1498	1815,	1836,
1334,	1335,	\@sd	1124, 1125, 1126,	1857,	1878,
1336,	1355,		1131, 1231,	1899,	2036,
1356,	1357,		1252, 1273,	2057,	2080,
1376,	1377,		1294, 1315,	2101,	2122,
1378,	1397,		1336, 1357,	2143, 2164, 2185	
1398,	1399,		1378, 1399,	\@sh	1127, 1129
1418,	1419,		1420, 1539,	\@showcubewidth . . .	
1420,	1539,		1560, 1581,	. . . . .	27, 30,
1540,	1541,		1602, 1623,		31, 32, 42, 43, 45
1560,	1561,		1644, 1665,	\@sqcx .	1132, 1478, 1499
1562,	1581,		1686, 1707,	\@sqcy .	1133, 1478, 1499
1582,	1583,		1728, 1750,	\@textRubikT . .	2559,
1602,	1603,		1771, 1792,		2584, 2592,
1604,	1623,		1813, 1834,		2600, 2608, 2616
1624,	1625,		1855, 1876,	\@textRubikTp .	2572,
1644,	1645,		1897, 2038,		2588, 2596,
1646,	1665,		2059, 2082,		2604, 2612, 2620
1666,	1667,		2103, 2124,	\@tlen . .	<u>1177</u> , 1185,
1686,	1687,		2145, 2166, 2187		1190, 1195,
1688,	1707,	\@sdd	1125, 1130, 1230,		1200, 1205,
1708,	1709,		1251, 1272,		1210, 1215,
1728,	1729,		1293, 1314,		1220, 1234,
1730,	1750,		1335, 1356,		1255, 1276,
1751,	1752,		1377, 1398,		1297, 1318,
1771,	1772,		1419, 1540,		1339, 1360,
1773,	1792,		1561, 1582,		1381, 1402,
1793,	1794,		1603, 1624,		1423, 1442,
1813,	1814,		1645, 1666,		1461, 1482,
1815,	1834,		1687, 1708,		1502, 1515,
1835,	1836,		1729, 1751,		1520, 1525,
1855,	1856,		1772, 1793,		1530, 1544,
1857,	1876,		1814, 1835,		1565, 1586,
1877,	1878,		1856, 1877,		1607, 1628,
1897,	1898,		1898, 2037,		1649, 1670,
1899,	2036,		2058, 2081,		1691, 1712,
2037,	2038,		2102, 2123,		1733, 1755,
2057,	2058,		2144, 2165, 2186		1776, 1797,
2059,	2080,	\@sddd . .	1126, 1229,		1818, 1839,
2081,	2082,		1250, 1271,		1860, 1881,
2101,	2102,		1292, 1313,		1902, 1914,
2103,	2122,		1334, 1355,		1919, 2012,
2123,	2124,		1376, 1397,		2017, 2022,
2143,	2144,		1418, 1541,		2027, 2041,
2145,	2164,		1562, 1583,		2063, 2085,

2106,	2127,	1429,	1448,	1238,	1248,
2148,	2169,	1467,	1488,	1259,	1269,
2190,	2388,	1508,	1550,	1280,	1290,
2393,	2398,	1571,	1592,	1301,	1311,
2403,	2538,	1613,	1634,	1322,	1332,
2543,	2548,	1655,	1676,	1343,	1353,
2553,	2623,	1697,	1718,	1364,	1374,
2628,	2721,	1739,	1761,	1385,	1395,
2726,	2731, 2736	1782,	1803,	1406,	1416,
\@xyzRubik . . .	1134,	1824,	1845,	1427,	1437,
2202,	2208,	1866,	1887,	1446,	1456,
2214,	2223, 2241	1908,	1929,	1465,	1475,
\@xyzRubikc		1940,	1951,	1486,	1496,
. . .	2255, 2264,	1962,	1973,	1506,	1537,
2270,	2276,	1984,	1995,	1548,	1558,
2282,	2288, 2294	2006,	2047,	1569,	1579,
\@xyzRubikcp		2069,	2091,	1590,	1600,
. . .	2255, 2267,	2112,	2133,	1611,	1621,
2273,	2279,	2154,	2175,	1632,	1642,
2285,	2291, 2297	2196,	2305,	1653,	1663,
\@xyzRubikp . . .	1134,	2316,	2327,	1674,	1684,
2205,	2211,	2338,	2349,	1695,	1705,
2217,	2224, 2242	2360,	2371,	1716,	1726,
\@xyzbdf1Rubik		2382,	2455,	1737,	1747,
. . .	1168, 2229,	2466,	2477,	1759,	1769,
2235,	2247, 2253	2488,	2499,	1780,	1790,
\@xyzbdf1Rubikp . . .		2510,	2521,	1801,	1811,
. . .	1170, 2230,	2532,	2565,	1822,	1832,
2236,	2248, 2254	2578,	2638,	1843,	1853,
\@xyzh	1134,	2649,	2660,	1864,	1874,
2203,	2209,	2671,	2682,	1885,	1895,
2215,	2221, 2239	2693,	2704, 2715	1906,	1927,
\@xyzhbdf1	1164, 2227,			1938,	1949,
2233,	2245, 2251			1960,	1971,
\@xyzhbdf1p		_	421	1982,	1993,
. . .	1166, 2228,			2004,	2034,
2234,	2246, 2252			2045,	2055,
\@xyzhc . . .	2255, 2265,			2067,	2078,
2271,	2277,			2089,	2099,
2283,	2289, 2295			2110,	2120,
\@xyzhcp	2255, 2268,	\B	25	2131,	2141,
2274,	2280,	\b	28	2152,	2162,
2286,	2292, 2298	\Ba	27	2173,	2183,
\@xyzhp	1134,	\Bc	29	2194,	2303,
2206,	2212,	\begin	32,	2314,	2325,
2218,	2222, 2240	34, 45, 47,	1086,	2336,	2347,
\ . . .	1240, 1261, 1282,	1088,	1095,	2358,	2369,
1303,	1324,	1097,	1104,	2380,	2453,
1345,	1366,	1106,	1113,	2464,	2475,
1387,	1408,	1115,	1227,	2486,	2497,

	2508,	2519,	848,	884,	904,	2005,	2046,
	2530,	2563,	938,	956,	978, 996	2068,	2090,
	2576,	2636,	\Bw	. . . . . 27		2111,	2132,
	2647,	2658,	\bw	775, 781, 790, 793,		2153,	2174,
	2669,	2680,		802, 810, 811,		2195,	2304,
	2691,	2702, 2713		818, 819, 820,		2315,	2326,
\bl	776, 782, 789, 792,			831, 849, 850,		2337,	2348,
	793, 798, 801,			884, 887, 905,		2359,	2370,
	802, 807, 811,			906, 941, 956,		2381,	2454,
	816, 820, 827,			957, 958, 978,		2465,	2476,
	830, 831, 846,			981, 996, 997, 998		2487,	2498,
	850, 883, 886,	\bx	. . . 596, 600, 601,			2509,	2520,
	887, 902, 906,		603, 604, 606,			2531,	2564,
	937, 940, 941,		607, 610, 611,			2577,	2637,
	954, 958, 977,		613, 614, 616,			2648,	2659,
	980, 981, 994, 998		617, 620, 621,			2670,	2681,
\Blb	. . . . . 106, 136,		623, 624, 626, 627			2692,	2703, 2714
	619, 692, 755,	\by	. . . 597, 600, 601,		\CF	. . . . . 29	
	836, 946, 963, 1003		603, 604, 606,		\CL	. . . . . 29	
\blh	. . . . . 789, 791,		607, 610, 611,		\cmd	. . . . . 564	
	798, 800, 807,		613, 614, 616,		\colorlet	. . . 21, 22, 23	
	808, 816, 817,		617, 620, 621,		\CR	. . . . . 29	
	827, 829, 846,		623, 624, 626, 627		\csname	. . . . . 1179	
	847, 883, 885,				\CU	. . . . . 29	
	902, 903, 937,				\cube@dxdydz	1013, 1015	
	939, 954, 955,	\CB	. . . . . 29		\Cubiedx	. . . 38, 1037,	
	977, 979, 994, 995	\CD	. . . . . 29			1039, 1089,	
\Blm	. . . . . 105, 135,	\centering	. . . . .			1098, 1107, 1116	
	609, 693, 835, 945		. . . 33, 46, 1087,		\Cubiedy	. . . 38, 1037,	
\Blt	. . . . . 104, 134,		1096, 1105,			1040, 1089,	
	599, 648, 694,		1114, 1239,			1098, 1107, 1116	
	834, 855, 911, 944		1260, 1281,		\cx	. . . . . 1037, 1047,	
\Bm	. . . . . 26		1302, 1323,			1050, 1058,	
\Bmb	. . . . . 106, 136,		1344, 1365,			1061, 1069,	
	622, 754, 962, 1002		1386, 1407,			1072, 1080, 1083	
\Bmm	. . . . . 105, 135, 612		1428, 1447,		\cy	. . . . . 1038, 1047,	
\Bmt	. . . . . 104, 134,		1466, 1487,			1050, 1058,	
	602, 647, 854, 910		1507, 1549,			1061, 1069,	
\Bp	. . . . . 25		1570, 1591,			1072, 1080, 1083	
\Brb	. . . . . 106, 136,		1612, 1633,		D		
	625, 707, 753,		1654, 1675,		\D	. . . . . 25	
	892, 961, 986, 1001		1696, 1717,		\d	. . . . . 28	
\Brm	. . . . . 105, 135,		1738, 1760,		\Da	. . . . . 27	
	615, 708, 891, 985		1781, 1802,		\Dc	. . . . . 29	
\Brt	. . . . . 104, 134,		1823, 1844,		\ddx	. . . 459, 463, 464,	
	605, 646, 709,		1865, 1886,			466, 467, 469,	
	853, 890, 909, 984		1907, 1928,			470, 473, 474,	
\Bs	. . . . . 27		1939, 1950,			476, 477, 479,	
\bs	777, 783, 790, 799,		1961, 1972,				
	809, 818, 828,		1983, 1994,				

	480, 483, 484,	287, 289, 292,	1252,	1271,
	486, 487, 489, 490	294, 296, 299,	1272,	1273,
<code>\ddy</code>	. . . 460, 463, 464,	301, 303, 307,	1292,	1293,
	466, 467, 469,	309, 311, 314,	1294,	1313,
	470, 473, 474,	316, 318, 321,	1314,	1315,
	476, 477, 479,	323, 325, 332,	1334,	1335,
	480, 483, 484,	334, 336, 339,	1336,	1355,
	486, 487, 489, 490	341, 343, 346,	1356,	1357,
<code>\def</code>	. . . . 2, 3, 79, 80,	348, 350, 354,	1376,	1377,
	81, 84, 85, 86,	356, 358, 361,	1378,	1397,
	89, 90, 91, 94,	363, 365, 368,	1398,	1399,
	95, 96, 99, 100,	370, 372, 379,	1418,	1419,
	101, 104, 105,	381, 383, 386,	1420,	1439,
	106, 109, 110,	388, 390, 393,	1458,	1477,
	111, 114, 115,	395, 397, 401,	1478,	1498,
	116, 119, 120,	403, 405, 408,	1499,	1539,
	121, 124, 125,	410, 412, 415,	1540,	1541,
	126, 129, 130,	417, 419, 427,	1560,	1561,
	131, 134, 135,	430, 433, 437,	1562,	1581,
	136, 179, 180,	440, 443, 447,	1582,	1583,
	183, 184, 187,	450, 453, 462,	1602,	1603,
	188, 191, 192,	465, 468, 472,	1604,	1623,
	195, 196, 199,	475, 478, 482,	1624,	1625,
	200, 203, 204,	485, 488, 497,	1644,	1645,
	207, 208, 784, 785	500, 503, 507,	1646,	1665,
<code>\definecolor</code>	. . . . .	510, 513, 517,	1666,	1667,
	. . . . 17, 18, 19, 20	520, 523, 532,	1686,	1687,
<code>\Dlb</code>	. . . 96, 131, 321,	535, 538, 542,	1688,	1707,
	368, 482, 715, 736	545, 548, 552,	1708,	1709,
<code>\Dlm</code>	. . . . . 95, 130,	555, 558, 567,	1728,	1729,
	314, 361, 472, 716	570, 573, 576,	1730,	1750,
<code>\Dlt</code>	94, 129, 307, 354,	579, 582, 585,	1751,	1752,
	462, 677, 717, 869	588, 591, 599,	1771,	1772,
<code>\Dm</code>	. . . . . 26	602, 605, 609,	1773,	1792,
<code>\Dmb</code>	. . . . . 96, 131,	612, 615, 619,	1793,	1794,
	323, 370, 485, 735	622, 625, 792,	1813,	1814,
<code>\Dmm</code>	95, 130, 316, 363, 475	801, 810, 819,	1815,	1834,
<code>\Dmt</code>	. . . 94, 129, 309,	830, 849, 886,	1835,	1836,
	356, 465, 678, 870	905, 940, 957,	1855,	1856,
<code>\Dp</code>	. . . . . 25	980, 997, 1026,	1857,	1876,
<code>\draw</code>	. . . . . 212,	1031, 1034,	1877,	1878,
	214, 216, 219,	1043, 1046,	1897,	1898,
	221, 223, 226,	1049, 1054,	1899,	2036,
	228, 230, 237,	1057, 1060,	2037,	2038,
	239, 241, 244,	1065, 1068,	2057,	2058,
	246, 248, 251,	1071, 1076,	2059,	2080,
	253, 255, 259,	1079, 1082,	2081,	2082,
	261, 263, 266,	1122, 1229,	2101,	2102,
	268, 270, 273,	1230, 1231,	2103,	2122,
	275, 277, 285,	1250, 1251,	2123,	2124,

2143, 2144,	\DrawRubikCubeSF ..	\DrawRubikCubeSidebarFR
2145, 2164,	..... 39, 40, 637	..... 920
2165, 2166,	\DrawRubikCubeSidebarBD	\DrawRubikCubeSidebarFRLD
2185, 2186, 2187	..... 967	..... 970
\DrawCubieLD	\DrawRubikCubeSidebarBDLD	\DrawRubikCubeSidebarFRLU
.. 1041, 1063, 1108	..... 1005	..... 914, 919, 970
\DrawCubieLU	\DrawRubikCubeSidebarBDRD	\DrawRubikCubeSidebarFU
.. 1041, 1074, 1117	..... 965	..... 928
\DrawCubieRD	\DrawRubikCubeSidebarBL	\DrawRubikCubeSidebarFULD
.. 1041, 1052, 1099	..... 896	..... 968
\DrawCubieRU	\DrawRubikCubeSidebarBLLD	\DrawRubikCubeSidebarFURD
.. 1041, 1041, 1090	..... 988	..... 922, 927, 968
\DrawCubieXY	\DrawRubikCubeSidebarBLLU	\DrawRubikCubeSidebarLB
38	..... 894	..... 895
\DrawNCubeAll . 44, 1006	\DrawRubikCubeSidebarBR	\DrawRubikCubeSidebarLBLD
\DrawNotationBox ..	..... 840	..... 983, 988
... 1121, 1228,	\DrawRubikCubeSidebarBRRD	\DrawRubikCubeSidebarLBLU
1249, 1270,	..... 948	..... 889, 894
1291, 1312,	\DrawRubikCubeSidebarBRRU	\DrawRubikCubeSidebarLF
1333, 1354,	..... 838	..... 867
1375, 1396,	\DrawRubikCubeSidebarBU	\DrawRubikCubeSidebarLFRD
1417, 1438,	..... 859	..... 931
1457, 1476,	\DrawRubikCubeSidebarBULU	\DrawRubikCubeSidebarLFRU
1497, 1538,	..... 913	..... 865, 931
1559, 1580,	\DrawRubikCubeSidebarBURU	\DrawRubikCubeSidebarRB
1601, 1622,	..... 857	..... 839
1643, 1664,	\DrawRubikCubeSidebarDB	\DrawRubikCubeSidebarRBRD
1685, 1706,	..... 966	..... 943, 948
1727, 1748,	\DrawRubikCubeSidebarDBLD	\DrawRubikCubeSidebarRBRU
1770, 1791,	..... 1000, 1005	..... 833, 838
1812, 1833,	\DrawRubikCubeSidebarDBRD	\DrawRubikCubeSidebarRF
1854, 1875,	..... 960, 965	..... 921
1896, 2035,	\DrawRubikCubeSidebarDF	\DrawRubikCubeSidebarRFLD
2056, 2079,	..... 875	..... 971
2100, 2121,	\DrawRubikCubeSidebarDFLU	\DrawRubikCubeSidebarRFLU
2142, 2163, 2184	..... 876	..... 919, 971
\DrawRubikCube 280, 280	\DrawRubikCubeSidebarDFRU	\DrawRubikCubeSidebarUB
\DrawRubikCubeF ...	..... 873, 876	..... 858
.. 39, 40, 564, 629	\DrawRubikCubeSidebarFD	\DrawRubikCubeSidebarUBLU
\DrawRubikCubeFrontFace	..... 874	..... 908, 913
..... 210,	\DrawRubikCubeSidebarFDLU	\DrawRubikCubeSidebarUBRU
234, 282, 329, 376	..... 877	..... 852, 857
\DrawRubikCubeLD ..	\DrawRubikCubeSidebarFDRU	\DrawRubikCubeSidebarUF
..... 328, 328	..... 868, 873, 877	..... 929
\DrawRubikCubeLU ..	\DrawRubikCubeSidebarFL	\DrawRubikCubeSidebarUFLD
..... 375, 375	..... 866	..... 969
\DrawRubikCubeRD ..	\DrawRubikCubeSidebarFLRD	\DrawRubikCubeSidebarUFRD
..... 281, 281	..... 930	..... 927, 969
\DrawRubikCubeRU ..	\DrawRubikCubeSidebarFLRU	\DrawRubikCubeXY .. 39
.. 233, 233, 280, 638	..... 860, 865, 930	\DrawRubikFaceB ... 768

\DrawRubikFaceBack .	\DrawRubikFlatUp . .	1305,	1316,
..... 41, 762, 768	..... 44, 423,	1326,	1337,
\DrawRubikFaceBackSide	423, 630, 644, 757	1347,	1358,
..... 41, 719, 774	\Drb ... 96, 131, 325,	1368,	1379,
\DrawRubikFaceBS .. 774	372, 488, 698, 734	1389,	1400,
\DrawRubikFaceD ... 764	\Drm 95, 130,	1410,	1421,
\DrawRubikFaceDown .	318, 365, 478, 697	1431,	1440,
..... 41, 758, 764	\Drt 94, 129, 311, 358,	1450,	1459,
\DrawRubikFaceDownSide	468, 679, 696, 871	1469,	1480,
..... 41, 738, 770	\Ds 27	1490,	1500,
\DrawRubikFaceDS .. 770	\Dw 27	1510,	1542,
\DrawRubikFaceF ... 767	\dx 790, 792, 793, 799,	1552,	1563,
\DrawRubikFaceFront	801, 802, 808,	1573,	1584,
..... 41, 761, 767	810, 811, 817,	1594,	1605,
\DrawRubikFaceFrontSide	819, 820, 828,	1615,	1626,
..... 41, 662, 773	830, 831, 847,	1636,	1647,
\DrawRubikFaceFS .. 773	849, 850, 884,	1657,	1668,
\DrawRubikFaceL ... 765	886, 887, 903,	1678,	1689,
\DrawRubikFaceLeft .	905, 906, 938,	1699,	1710,
..... 41, 759, 765	940, 941, 955,	1720,	1731,
\DrawRubikFaceLeftSide	957, 958, 978,	1741,	1753,
..... 41, 700, 771	980, 981, 995,	1763,	1774,
\DrawRubikFaceLS .. 771	997, 998, 1016,	1784,	1795,
\DrawRubikFaceR ... 766	1027, 1032, 1035	1805,	1816,
\DrawRubikFaceRight	\dy 791, 792, 793, 800,	1826,	1837,
..... 41, 760, 766	801, 802, 809,	1847,	1858,
\DrawRubikFaceRightSide	810, 811, 818,	1868,	1879,
..... 41, 681, 772	819, 820, 829,	1889,	1900,
\DrawRubikFaceRS .. 772	830, 831, 848,	1910,	1931,
\DrawRubikFaceU ... 763	849, 850, 885,	1942,	1953,
\DrawRubikFaceUp ..	886, 887, 904,	1964,	1975,
..... 41, 757, 763	905, 906, 939,	1986,	1997,
\DrawRubikFaceUpSide	940, 941, 956,	2008,	2039,
..... 41, 643, 769	957, 958, 979,	2049,	2060,
\DrawRubikFaceUS .. 769	980, 981, 996,	2071,	2083,
\DrawRubikFlatBack .	997, 998, 1019,	2093,	2104,
.. 44, 423, 595,	1027, 1032, 1035	2114,	2125,
635, 641, 720, 762	\dz 1022, 1027, 1032, 1035	2135,	2146,
\DrawRubikFlatDown .		2156,	2167,
.. 44, 423, 458,		2177,	2188,
631, 639, 739, 758		2198,	2307,
\DrawRubikFlatFront	E	2318,	2329,
..... 44, 423,	\E 26	2340,	2351,
563, 633, 663, 761	\end 36,	2362,	2373,
\DrawRubikFlatLeft .	37, 49, 50, 1091,	2384,	2457,
.. 44, 423, 493,	1092, 1100,	2468,	2479,
632, 640, 701, 759	1101, 1109,	2490,	2501,
\DrawRubikFlatRight	1110, 1118,	2512,	2523,
..... 44, 423,	1119, 1232,	2534,	2567,
528, 634, 682, 760	1242, 1253,	2580,	2640,
	1263, 1274,		
	1284, 1295,		

2651, 2662, 2673, 2684, 2695, 2706, 2717					
\endcsname	1179				
\Ep	26				
\equal	788, 797, 806, 815, 826, 845, 882, 901, 936, 953, 976, 993				
\expandafter	1179				
F					
\F	25				
\f	28				
\Fa	27				
\fbox 60, 67, 76, 77, 1174					
\fboxrule	41, 1173				
\fboxsep	29, 40, 1172				
\Fc	29				
\Flb 86, 116, 203, 208, 226, 585, 711, 741					
\Flm	85, 115, 187, 192, 195, 200, 219, 576, 712				
\Flt 84, 114, 179, 184, 212, 567, 658, 713					
\Fm	26				
\Fmb	86, 116, 203, 208, 228, 588, 742				
\Fmm 85, 115, 187, 192, 195, 200, 221, 579					
\Fmt	84, 114, 179, 184, 214, 570, 659				
\fontsize	24, 25				
\foreach 1010, 1011, 1012					
\ForEachX	55, 61, 66				
\Fp	25				
\framebox	44				
\Frb 86, 116, 203, 208, 230, 591, 688, 743					
\Frm	85, 115, 187, 192, 195, 200, 223, 582, 689				
\Frt 84, 114, 179, 184, 216, 573, 660, 690					
\Fs	27				
\Fw	27				
H					
\height	1234, 1255, 1276, 1297, 1318, 1339, 1360, 1381, 1402, 1423, 1442, 1461, 1482, 1502, 1544, 1565, 1586, 1607, 1628, 1649, 1670, 1691, 1712, 1733, 1755, 1776, 1797, 1818, 1839, 1860, 1881, 1902, 2041, 2063, 2085, 2106, 2127, 2148, 2169, 2190				
\hspace	1177				
I					
\ifthenelse	56, 62, 67, 788, 797, 806, 815, 826, 845, 882, 901, 936, 953, 976, 993				
L					
\L	25				
\l	28				
\La	27				
\Lc	29				
\Llb 101, 126, 207, 346, 393, 517, 730, 745					
\Llm 100, 125, 191, 199, 339, 386, 507, 731					
\Llt 99, 124, 183, 332, 379, 497, 652, 732					
\Lm	26				
\Lmb	101, 126, 207, 348, 395, 520, 746				
\Lmm	100, 125, 191, 199, 341, 388, 510				
\Lmt	99, 124, 183, 334, 381, 500, 651				
\Lp	25				
\Lrb	101, 126, 207, 350, 397, 523, 669, 747, 863				
\Lrm	100, 125, 191, 199, 343, 390, 513, 670, 862				
\Lrt	99, 124, 183, 336, 383, 503, 650, 671, 861				
\Ls	27				
\Lw	27				
\lx	494, 498, 499, 501, 502, 504, 505, 508, 509, 511, 512, 514, 515, 518, 519, 521, 522, 524, 525				
\ly	495, 498, 499, 501, 502, 504, 505, 508, 509, 511, 512, 514, 515, 518, 519, 521, 522, 524, 525				
M					
\M	26				
\MB	26				
\mbox	74, 75, 76, 77				
\MD	26				
\MF	26				
\ML	26				
\Mp	26				
\MR	26				
\MU	26				
N					
\ncubes	1007, 1010, 1011, 1012				
\NeedsTeXFormat	4				
\newcommand 15, 16, 24, 25, 26, 28, 39, 52, 53, 54, 59, 65, 70, 71, 72, 73, 74, 75, 76, 77, 78, 83, 88, 93, 98, 103, 108, 113, 118, 123, 128, 133, 144, 152, 153, 154, 156, 164, 165,					

173,	174,	175,	1142,	1143,	1349,	1350,
176,	177,	178,	1144,	1145,	1352,	1360,
182,	186,	190,	1146,	1147,	1362,	1370,
194,	198,	202,	1148,	1149,	1371,	1373,
206,	210,	233,	1150,	1151,	1381,	1383,
280,	281,	328,	1152,	1153,	1391,	1392,
375,	423,	458,	1154,	1155,	1394,	1402,
493,	528,	563,	1156,	1157,	1404,	1412,
595,	629,	637,	1158,	1159,	1413,	1415,
643,	662,	681,	1160,	1162,	1423,	1425,
700,	719,	738,	1164,	1166,	1433,	1434,
757,	758,	759,	1168,	1170,	1436,	1442,
760,	761,	762,	1172,	1177,	1444,	1452,
763,	764,	765,	1178,	1180,	1453,	1455,
766,	767,	768,	1181,	1182,	1461,	1463,
769,	770,	771,	1183,	1184,	1471,	1472,
772,	773,	774,	1185,	1186,	1474,	1482,
775,	776,	777,	1187,	1188,	1484,	1492,
781,	782,	783,	1189,	1190,	1493,	1495,
785,	786,	795,	1191,	1192,	1502,	1504,
804,	813,	822,	1193,	1194,	1512,	1514,
833,	838,	839,	1195,	1196,	1515,	1516,
840,	841,	852,	1197,	1198,	1517,	1518,
857,	858,	859,	1199,	1200,	1519,	1520,
860,	865,	866,	1201,	1202,	1521,	1522,
867,	868,	873,	1203,	1204,	1523,	1524,
874,	875,	876,	1205,	1206,	1525,	1526,
877,	878,	889,	1207,	1208,	1527,	1528,
894,	895,	896,	1209,	1210,	1529,	1530,
897,	908,	913,	1211,	1212,	1531,	1532,
914,	919,	920,	1213,	1214,	1533,	1534,
921,	922,	927,	1215,	1216,	1536,	1544,
928,	929,	930,	1217,	1218,	1546,	1554,
931,	932,	943,	1219,	1220,	1555,	1557,
948,	949,	960,	1221,	1222,	1565,	1567,
965,	966,	967,	1223,	1224,	1575,	1576,
968,	969,	970,	1226,	1234,	1578,	1586,
971,	972,	983,	1236,	1244,	1588,	1596,
988,	989,	1000,	1245,	1247,	1597,	1599,
1005,	1006,		1255,	1257,	1607,	1609,
1015,	1037,		1265,	1266,	1617,	1618,
1038,	1041,		1268,	1276,	1620,	1628,
1052,	1063,		1278,	1286,	1630,	1638,
1074,	1085,		1287,	1289,	1639,	1641,
1094,	1103,		1297,	1299,	1649,	1651,
1112,	1121,		1307,	1308,	1659,	1660,
1134,	1135,		1310,	1318,	1662,	1670,
1136,	1137,		1320,	1328,	1672,	1680,
1138,	1139,		1329,	1331,	1681,	1683,
1140,	1141,		1339,	1341,	1691,	1693,

1701,	1702,	2018,	2019,	2248,	2249,
1704,	1712,	2020,	2021,	2250,	2251,
1714,	1722,	2022,	2023,	2252,	2253,
1723,	1725,	2024,	2025,	2254,	2255,
1733,	1735,	2026,	2027,	2257,	2259,
1743,	1744,	2028,	2029,	2261,	2263,
1746,	1755,	2030,	2031,	2264,	2265,
1757,	1765,	2033,	2041,	2266,	2267,
1766,	1768,	2043,	2051,	2268,	2269,
1776,	1778,	2052,	2054,	2270,	2271,
1786,	1787,	2063,	2065,	2272,	2273,
1789,	1797,	2074,	2075,	2274,	2275,
1799,	1807,	2077,	2085,	2276,	2277,
1808,	1810,	2087,	2095,	2278,	2279,
1818,	1820,	2096,	2098,	2280,	2281,
1828,	1829,	2106,	2108,	2282,	2283,
1831,	1839,	2116,	2117,	2284,	2285,
1841,	1849,	2119,	2127,	2286,	2287,
1850,	1852,	2129,	2137,	2288,	2289,
1860,	1862,	2138,	2140,	2290,	2291,
1870,	1871,	2148,	2150,	2292,	2293,
1873,	1881,	2158,	2159,	2294,	2295,
1883,	1891,	2161,	2169,	2296,	2297,
1892,	1894,	2171,	2179,	2298,	2299,
1902,	1904,	2180,	2182,	2300,	2301,
1912,	1913,	2190,	2192,	2309,	2310,
1914,	1915,	2200,	2201,	2311,	2312,
1916,	1917,	2202,	2203,	2320,	2321,
1918,	1919,	2204,	2205,	2322,	2323,
1920,	1921,	2206,	2207,	2331,	2332,
1922,	1923,	2208,	2209,	2333,	2334,
1924,	1925,	2210,	2211,	2342,	2343,
1933,	1934,	2212,	2213,	2344,	2345,
1935,	1936,	2214,	2215,	2353,	2354,
1944,	1945,	2216,	2217,	2355,	2356,
1946,	1947,	2218,	2219,	2364,	2365,
1955,	1956,	2220,	2221,	2366,	2367,
1957,	1958,	2222,	2223,	2375,	2376,
1966,	1967,	2224,	2225,	2377,	2378,
1968,	1969,	2226,	2227,	2386,	2387,
1977,	1978,	2228,	2229,	2388,	2389,
1979,	1980,	2230,	2231,	2390,	2391,
1988,	1989,	2232,	2233,	2392,	2393,
1990,	1991,	2234,	2235,	2394,	2395,
1999,	2000,	2236,	2237,	2396,	2397,
2001,	2002,	2238,	2239,	2398,	2399,
2010,	2011,	2240,	2241,	2400,	2401,
2012,	2013,	2242,	2243,	2402,	2403,
2014,	2015,	2244,	2245,	2404,	2405,
2016,	2017,	2246,	2247,	2406,	2407,

2408,	2409,	2583,	2584,	2739,	2740,
2411,	2413,	2585,	2586,	2741,	2742,
2414,	2415,	2587,	2588,	2743,	2744,
2416,	2417,	2589,	2590,	2745,	2746,
2418,	2419,	2591,	2592,	2747,	2748,
2420,	2421,	2593,	2594,	2749,	2750,
2422,	2423,	2595,	2596,	2751,	2752,
2424,	2425,	2597,	2598,	2753,	2754,
2426,	2427,	2599,	2600,	2755,	2756,
2428,	2429,	2601,	2602,	2757,	2758,
2430,	2431,	2603,	2604,	2759,	2760,
2432,	2433,	2605,	2606,	2761,	2762,
2434,	2435,	2607,	2608,	2763,	2764,
2436,	2437,	2609,	2610,	2765,	2766,
2438,	2439,	2611,	2612,	2767,	2768,
2440,	2441,	2613,	2614,	2769,	2770,
2442,	2443,	2615,	2616,	2771,	2772,
2444,	2445,	2617,	2618,	2773,	2774,
2446,	2447,	2619,	2620,	2775,	2776,
2448,	2449,	2621,	2622,	2777,	2778,
2450,	2451,	2623,	2624,	2779,	2780, 2781
2459,	2460,	2625,	2626,	\newlength ... 27, 1175	
2461,	2462,	2627,	2628,	\no@sidebar	
2470,	2471,	2629,	2630,	. 784, 788, 797,	
2472,	2473,	2631,	2632,	806, 815, 826,	
2481,	2482,	2633,	2634,	845, 882, 901,	
2483,	2484,	2642,	2643,	936, 953, 976, 993	
2492,	2493,	2644,	2645,	\node 1479	
2494,	2495,	2653,	2654,	\NoSidebar 42, 785	
2503,	2504,	2655,	2656,		
2505,	2506,	2664,	2665,	O	
2514,	2515,	2666,	2667,	\overbrace 74, 76	
2516,	2517,	2675,	2676,		
2525,	2526,	2677,	2678,	P	
2527,	2528,	2686,	2687,	\pgfmathsetmacro ..	
2536,	2537,	2688,	2689,	.... 424, 425,	
2538,	2539,	2697,	2698,	459, 460, 494,	
2540,	2541,	2699,	2700,	495, 529, 530,	
2542,	2543,	2708,	2709,	596, 597, 775,	
2544,	2545,	2710,	2711,	776, 777, 781,	
2546,	2547,	2719,	2720,	782, 783, 789,	
2548,	2549,	2721,	2722,	790, 791, 798,	
2550,	2551,	2723,	2724,	799, 800, 807,	
2552,	2553,	2725,	2726,	808, 809, 816,	
2554,	2555,	2727,	2728,	817, 818, 827,	
2556,	2557,	2729,	2730,	828, 829, 846,	
2558,	2559,	2731,	2732,	847, 848, 883,	
2561,	2570,	2733,	2734,	884, 885, 902,	
2571,	2572,	2735,	2736,	903, 904, 937,	
2574,	2582,	2737,	2738,	938, 939, 954,	

955, 956, 977,	1921,	2013,	\Rrb 91, 121, 204, 277,
978, 979, 994,	2014,	2018,	303, 558, 726, 749
995, 996, 1007,	2019,	2023,	\rrB 1184
1016, 1019,	2024,	2028,	\rrb 2249
1022, 1037,	2029,	2041,	\rrBa 1214
1038, 1124,	2063,	2085,	\rrBap 1219
1125, 1126,	2106,	2127,	\rrBc 2293
1127, 1128,	2148,	2169,	\rrBcp 2296
1129, 1130,	2190,	2255,	\rrBm 2397
1131, 1132, 1133	2257,	2259,	\rrBmp 2402
\ProvidesPackage ... 5	2260,	2261,	\rrBp 1189
R	2262,	2389,	\rrbp 2250
\R 25	2390,	2394,	\rrBs 1204
\r 28	2395,	2399,	\rrBsp 1209
\Ra 27	2400,	2404,	\rrBw 1194
\raisebox 1159 ,	2405,	2407,	\rrBwp 1199
1161, 1163,	2408,	2410,	\rrCB 2443
1165, 1167,	2412,	2539,	\rrCBp 2446
1169, 1171,	2540,	2544,	\rrCD 2431
1174, 1186,	2545,	2549,	\rrCDp 2434
1187, 1191,	2550,	2554,	\rrCF 2437
1192, 1196,	2555,	2624,	\rrCFp 2440
1197, 1201,	2626,	2629,	\rrCL 2419
1202, 1206,	2631,	2722,	\rrCLp 2422
1207, 1211,	2723,	2727,	\rrCR 2413
1212, 1216,	2728,	2732,	\rrCRp 2416
1217, 1221,	2733, 2737, 2738		\rrCU 2425
1222, 1234,	\Rc 29		\rrCUp 2428
1255, 1276,	\RCfiledate 3, 5		\rrD 1224
1297, 1318,	\RCfileversion ... 2, 5		\rrd 2225
1339, 1360,	\relax 31, 43		\rrDa 1350
1381, 1402,	\RequirePackage 8, 11, 14		\rrDap 1371
1423, 1442,	\Rlb 91, 121,		\rrDc 2281
1461, 1482,	204, 273, 299,		\rrDcp 2284
1502, 1516,	552, 673, 751, 917		\rrDm 2365
1517, 1521,	\Rlm 90, 120,		\rrDmp 2376
1522, 1526,	188, 196, 266,		\rrDp 1245
1527, 1531,	292, 542, 674, 916		\rrdp 2226
1532, 1544,	\Rlt 89, 119,		\rrDs 1308
1565, 1586,	180, 259, 285,		\rrDsp 1329
1607, 1628,	532, 654, 675, 915		\rrDw 1266
1649, 1670,	\Rm 26		\rrDwp 1287
1691, 1712,	\Rmb ... 91, 121, 204,		\rrE 1392
1733, 1755,	275, 301, 555, 750		\rrEp 1413
1776, 1797,	\Rmm ... 90, 120, 188,		\rrF 1434
1818, 1839,	196, 268, 294, 545		\rrf 2243
1860, 1881,	\Rmt ... 89, 119, 180,		\rrFa 1524
1902, 1915,	261, 287, 535, 655		\rrFap 1529
1916, 1920,	\Rp 25		\rrFc 2287
	\rr 25, 1180		\rrFcp 2290

\rrFm	2387	\rrhE . . .	1392 , 1935 ,	\rrhMF	2537
\rrFmp	2392		1944 , 1946 ,	\rrhMFp	2542
\rrFp	1453		1955 , 2355 ,	\rrhML	2471
\rrfp	2244		2364 , 2366 ,	\rrhMLp	2482
\rrFs	1514		2375 , 2505 ,	\rrhMp . .	1723 , 1979 ,
\rrFsp	1519		2514 , 2516 , 2525		1988 , 1990 ,
\rrFw	1472	\rrhEp . .	1413 , 1924 ,		1999 , 2300 ,
\rrFwp	1493		1933 , 1957 ,		2309 , 2333 ,
\rrh .	25 , 1180 , 2558 ,		1966 , 2344 ,		2342 , 2450 ,
	2559 , 2571 , 2572		2353 , 2377 ,		2459 , 2483 , 2492
\rrhB	1184		2386 , 2494 ,	\rrhMR	2449
\rrhb	2249 , 2756		2503 , 2527 , 2536	\rrhMRp	2460
\rrhBa	1214	\rrhF	1434	\rrhMU	2493
\rrhBap	1219	\rrhf	2243 , 2754	\rrhMUp	2504
\rrhBc	2293 , 2768	\rrhFa	1524	\rrhR	1744
\rrhBcp	2296 , 2769	\rrhFap	1529	\rrhr	2237 , 2748
\rrhBm	2397	\rrhFc	2287 , 2766	\rrhRa	1871
\rrhBmp	2402	\rrhFcp	2290 , 2767	\rrhRap	1892
\rrhBp	1189	\rrhFm	2387	\rrhRc	2263 , 2760
\rrhbp	2252 , 2757	\rrhFmp	2392	\rrhRcp	2266 , 2761
\rrhBs	1204	\rrhFp	1453	\rrhRm	2299
\rrhBsp	1209	\rrhfp	2246 , 2755	\rrhRmp	2310
\rrhBw	1194	\rrhFs	1514	\rrhRp	1766
\rrhBwp	1199	\rrhFsp	1519	\rrhrp	2240 , 2749
\rrhCB	2443 , 2780	\rrhFw	1472	\rrhRs .	1829 , 2633 , 2642
\rrhCBp	2446 , 2781	\rrhFwp	1493	\rrhRsp .	1850 , 2644 , 2653
\rrhCD	2431 , 2776	\rrhL	1534	\rrhRw	1787
\rrhCDp	2434 , 2777	\rrhl	2231 , 2746	\rrhRwp	1808
\rrhCF	2437 , 2778	\rrhLa	1660	\rrhS	1913
\rrhCFp	2440 , 2779	\rrhLap	1681	\rrhSB	2730
\rrhCL	2419 , 2770	\rrhLc	2269 , 2758	\rrhSb	2021
\rrhCLp	2422 , 2771	\rrhLcp	2272 , 2759	\rrhSBp	2735
\rrhCR	2413 , 2772	\rrhLm	2321	\rrhSbp	2026
\rrhCRp	2416 , 2773	\rrhLmp	2332	\rrhSD	2698
\rrhCU	2425 , 2774	\rrhLp	1555	\rrhSd	1945
\rrhCUp	2428 , 2775	\rrhlp	2234 , 2747	\rrhSDp	2709
\rrhD	1224	\rrhLs .	1618 , 2655 , 2664	\rrhSdp	1956
\rrhd	2225 , 2752	\rrhLsp .	1639 , 2666 , 2675	\rrhSF	2720
\rrhDa	1350	\rrhLw	1576	\rrhSf	2011
\rrhDap	1371	\rrhLwp	1597	\rrhSFp	2725
\rrhDc	2281 , 2764	\rrhM . . .	1702 , 1968 ,	\rrhSfp	2016
\rrhDcp	2284 , 2765		1977 , 2001 ,	\rrhSL	2654
\rrhDm	2365		2010 , 2311 ,	\rrhSl	1967
\rrhDmp	2376		2320 , 2322 ,	\rrhSLp	2665
\rrhDp	1245		2331 , 2461 ,	\rrhSlp	1978
\rrhdp	2228 , 2753		2470 , 2472 , 2481	\rrhSp	1918
\rrhDs .	1308 , 2699 , 2708	\rrhMB	2547	\rrhSR	2632
\rrhDsp .	1329 , 2710 , 2719	\rrhMBp	2552	\rrhSr	1989
\rrhDw	1266	\rrhMD	2515	\rrhSRp	2643
\rrhDwp	1287	\rrhMDp	2526	\rrhSrp	2000

\rrhSU	2676	\rrLw	1576	\rrSR	2632
\rrhSu	1923	\rrLwp	1597	\rrSr	1989
\rrhSup	2687	\Rrm	90, 120, 188, 196, 270, 296, 548, 727	\rrSRp	2643
\rrhSup	1934	\rrM	1702	\rrSrp	2000
\rrhTB	2622	\rrMB	2547	\rrSU	2676
\rrhTBp	2627	\rrMBp	2552	\rrSu	1923
\rrhTD	2606	\rrMD	2515	\rrSUP	2687
\rrhTDp	2610	\rrMDp	2526	\rrSup	1934
\rrhTF	2614	\rrMF	2537	\Rrt	89, 119, 180, 263, 289, 538, 656, 728
\rrhTFp	2618	\rrMFp	2542	\rrTB	2622
\rrhTL	2582	\rrML	2471	\rrTBp	2627
\rrhTLp	2586	\rrMLp	2482	\rrTD	2606
\rrhTR	2590	\rrMp	1723	\rrTDp	2610
\rrhTRp	2594	\rrMR	2449	\rrTF	2614
\rrhTU	2598	\rrMRp	2460	\rrTFp	2618
\rrhTUp	2602	\rrMU	2493	\rrTL	2582
\rrhU	2031	\rrMUp	2504	\rrTLp	2586
\rrhu	2219, 2750	\rrR	1744	\rrTR	2590
\rrhUa	2159	\rrr	2237	\rrTRp	2594
\rrhUap	2180	\rrRa	1871	\rrTU	2598
\rrhUc	2275, 2762	\rrRap	1892	\rrTUp	2602
\rrhUcp	2278, 2763	\rrRc	2263	\rrU	2031
\rrhUm	2343	\rrRcp	2266	\rru	2219
\rrhUmp	2354	\rrRm	2299	\rrUa	2159
\rrhUp	2075	\rrRmp	2310	\rrUap	2180
\rrhup	2222, 2751	\rrRp	1766	\rrUc	2275
\rrhUs	2117, 2138, 2677, 2686	\rrrp	2238	\rrUcp	2278
\rrhUsp	2148, 2158, 2688, 2697	\rrRs	1829	\rrUm	2343
\rrhUw	2052	\rrRsp	1850	\rrUmp	2354
\rrhUwp	2096	\rrRw	1787	\rrUp	2075
\rrhx	2201, 2740	\rrRwp	1808	\rrup	2220
\rrhxp	2204, 2741	\rrS	1913	\rrUs	2117
\rrhy	2207, 2742	\rrSB	2730	\rrUsp	2138
\rrhyp	2210, 2743	\rrSb	2021	\rrUw	2052
\rrhz	2213, 2744	\rrSBp	2735	\rrUwp	2096
\rrhzp	2216, 2745	\rrSbp	2026	\rrx	2201
\rrL	1534	\rrSD	2698	\rrxp	2204
\rrl	2231	\rrSd	1945	\rry	2207
\rrLa	1660	\rrSDp	2709	\rryp	2210
\rrLap	1681	\rrSdp	1956	\rrz	2213
\rrLc	2269	\rrSF	2720	\rrzp	2216
\rrLcp	2272	\rrSf	2011	\Rs	27
\rrLm	2321	\rrSFp	2725	\Rubik	25, 1180
\rrLmp	2332	\rrSfp	2016	\RubikB	1184
\rrLp	1555	\rrSL	2654	\Rubikb	2249
\rrlp	2232	\rrSl	1967	\RubikBa	1214
\rrLs	1618	\rrSLp	2665	\RubikBap	1219
\rrLsp	1639	\rrSlp	1978	\RubikBc	2293
		\rrSp	1918	\RubikBcp	2296

\RubikBm	2397	\RubikDw	1266	\RubikLcp	2272
\RubikBmp	2402	\RubikDwp	1287	\RubikLm	2321
\RubikBp	1189	\RubikE	1392	\RubikLmp	2332
\Rubikbp	2254	\RubikEp	1413	\RubikLp	1555
\RubikBs	1204	\RubikF	1434	\Rubiklp	2236
\RubikBsp	1209	\Rubikf	2243	\RubikLs	1618
\RubikBw	1194	\RubikFa	1524	\RubikLsp	1639
\RubikBwp	1199	\RubikFace..	19	\RubikLw	1576
\RubikCB	2443	\RubikFaceBack	20,	\RubikLwp	1597
\RubikCBp	2446	78, 103, 150, 162		\RubikM	1702
\RubikCD	2431	\RubikFaceBackAll	20,	\RubikMB	2547
\RubikCDp	2434	108, 133, 143, 171		\RubikMBp	2552
\RubikCF	2437	\RubikFaceDown	...	\RubikMD	2515
\RubikCFp	2440	20, 78, 93, 148, 160		\RubikMDp	2526
\RubikCL	2419	\RubikFaceDownAll	20,	\RubikMF	2537
\RubikCLp	2422	108, 128, 139, 169		\RubikMfp	2542
\RubikCR	2413	\RubikFaceFront	...	\RubikML	2471
\RubikCRp	2416	20, 78, 83, 149, 161		\RubikMLp	2482
\RubikCU	2425	\RubikFaceFrontAll	...	\RubikMp	1723
\Rubikcube	16	20,		\RubikMR	2449
\rubikcube	11, 15	108, 113, 142, 170		\RubikMRp	2460
\RubikCubeGray	152	\RubikFaceLeft	...	\RubikMU	2493
\RubikCubeGrayAll	174	20, 78, 98, 146, 158		\RubikMUp	2504
\RubikCubeGrayWB	164	\RubikFaceLeftAll	20,	\RubikR	1744
\RubikCubeGrayWY	154	108, 123, 140, 167		\Rubikr	2237
\RubikCubeGrey	144	\RubikFaceRight	...	\RubikRa	1871
\RubikCubeGrey..	19	20, 78, 88, 145, 157		\RubikRap	1892
\RubikCubeGreyAll	...	\RubikFaceRightAll	...	\RubikRc	2263
19, 23, 173		20,		\RubikRcp	2266
\RubikCubeGreyWB	23, 144	108, 118, 141, 166		\RubikRm	2299
\RubikCubeGreyWY	23, 144	\RubikFaceUp	...	\RubikRmp	2310
\RubikCubeSolved	21, 175	20, 78, 78, 147, 159		\RubikRp	1766
\RubikCubeSolved..	19	\RubikFaceUpAll	20,	\Rubikrp	2242
\RubikCubeSolvedWB	...	108, 108, 138, 168		\RubikRs	1829
22, 175		\RubikFap	1529	\RubikRsp	1850
\RubikCubeSolvedWY	...	\RubikFc	2287	\RubikRw	1787
21, 175		\RubikFcp	2290	\RubikRwp	1808
\RubikCUp	2428	\RubikFm	2387	\RubikS	1913
\RubikD	1224	\RubikFmp	2392	\RubikSB	2730
\Rubikd	2225	\RubikFp	1453	\RubikSb	2021
\RubikDa	1350	\Rubikfp	2248	\RubikSBp	2735
\RubikDap	1371	\RubikFs	1514	\RubikSbp	2026
\RubikDc	2281	\RubikFsp	1519	\RubikSD	2698
\RubikDcp	2284	\RubikFw	1472	\RubikSd	1945
\RubikDm	2365	\RubikFwp	1493	\RubikSDp	2709
\RubikDmp	2376	\RubikL	1534	\RubikSdp	1956
\RubikDp	1245	\Rubikl	2231	\RubikSF	2720
\Rubikdp	2230	\RubikLa	1660	\RubikSf	2011
\RubikDs	1308	\RubikLap	1681	\RubikSfp	2725
\RubikDsp	1329	\RubikLc	2269	\RubikSfp	2016

- \RubikSideBarLength [782](#)
 \RubikSideBarLength . [42, 775, 776, 779](#)
 \RubikSideBarSep . [783](#)
 \RubikSideBarSep . . [42, 775, 777, 780](#)
 \RubikSideBarWidth . [781](#)
 \RubikSideBarWidth . . [42, 775, 775, 778](#)
 \RubikSL [2654](#)
 \RubikSl [1967](#)
 \RubikSlice [19](#)
 \RubikSliceBottomL . [178](#)
 \RubikSliceBottomR . [178](#)
 \RubikSliceBottomX . [23](#)
 \RubikSliceEquatorL . [198](#)
 \RubikSliceEquatorR . [194](#)
 \RubikSliceMiddleL . [178](#)
 \RubikSliceMiddleR . [178](#)
 \RubikSliceMiddleX . [23](#)
 \RubikSliceTopL . . . [178](#)
 \RubikSliceTopR . . . [178](#)
 \RubikSliceTopX . . . [23](#)
 \RubikSLp [2665](#)
 \RubikSlp [1978](#)
 \RubikSolvedConfig .
 [21](#),
 [165, 173, 175, 177](#)
 \RubikSp [1918](#)
 \RubikSR [2632](#)
 \RubikSr [1989](#)
 \RubikSRp [2643](#)
 \RubikSrp [2000](#)
 \RubikSU [2676](#)
 \RubikSu [1923](#)
 \RubikSUP [2687](#)
 \RubikSup [1934](#)
 \RubikTB [2622](#)
 \RubikTBp [2627](#)
 \RubikTD [2606](#)
 \RubikTDp [2610](#)
 \RubikTF [2614](#)
 \RubikTFp [2618](#)
 \RubikTL [2582](#)
 \RubikTLp [2586](#)
 \RubikTR [2590](#)
 \RubikTRp [2594](#)
 \RubikTU [2598](#)
 \RubikTUp [2602](#)
 \RubikU [2031](#)
 \Rubiku [2219](#)
 \RubikUa [2159](#)
 \RubikUap [2180](#)
 \RubikUc [2275](#)
 \RubikUcp [2278](#)
 \RubikUm [2343](#)
 \RubikUmp [2354](#)
 \RubikUp [2075](#)
 \Rubikup [2224](#)
 \RubikUs [2117, 2138](#)
 \RubikUsp [2150](#)
 \RubikUw [2052](#)
 \RubikUwp [2096](#)
 \Rubikx [2201](#)
 \Rubikxp [2204](#)
 \Rubiky [2207](#)
 \Rubikyp [2210](#)
 \Rubikz [2213](#)
 \Rubikzp [2216](#)
 \rule [1174](#)
 \Rw [27](#)
 \rx [529, 533, 534](#),
 [536, 537, 539](#),
 [540, 543, 544](#),
 [546, 547, 549](#),
 [550, 553, 554](#),
 [556, 557, 559, 560](#)
 \ry [530, 533, 534](#),
 [536, 537, 539](#),
 [540, 543, 544](#),
 [546, 547, 549](#),
 [550, 553, 554](#),
 [556, 557, 559, 560](#)

 S
 \S [26](#)
 \SB [27](#)
 \Sb [27](#)
 \SD [27](#)
 \Sd [27](#)
 \SequenceBraceA . [47, 74](#)
 \SequenceBraceAF . [47, 76](#)
 \SequenceBraceB . [47, 74](#)
 \SequenceBraceBF . [47, 77](#)
 \SequenceInfo [70](#)
 \SequenceLong [70](#)
 \SequenceName [70](#)
 \SequenceShort [70](#)
 \setlength
 . [29, 30, 40, 41](#),
 [42, 1172, 1173, 1176](#)
 \SF [27](#)
 \Sf [27](#)
 \ShowCube [16, 27](#)
 \ShowCubeF [16, 27](#)
 \ShowSequence [45, 52](#)
 \ShowSequenceF [45, 52](#)
 \ShowSequencef [45, 52](#)
 \side@barB [658](#),
 [659, 660, 677](#),
 [678, 679, 696](#),
 [697, 698, 715](#),
 [716, 717, 734](#),
 [735, 736, 753](#),
 [754, 755, 784](#),
 [813, 869, 870, 871](#)
 \side@barL [650](#),
 [651, 652, 669](#),
 [670, 671, 688](#),
 [689, 690, 707](#),
 [708, 709, 726](#),
 [727, 728, 745](#),
 [746, 747, 784](#),
 [786, 861, 862, 863](#)
 \side@barR [654](#),
 [655, 656, 673](#),
 [674, 675, 692](#),
 [693, 694, 711](#),
 [712, 713, 730](#),
 [731, 732, 749](#),
 [750, 751, 784](#),
 [795, 915, 916, 917](#)
 \side@barRubikBbackLD
 [989](#),
 [1001, 1002, 1003](#)
 \side@barRubikBbackRD
 . [949, 961, 962, 963](#)
 \side@barRubikLbackLD
 . [972, 984, 985, 986](#)
 \side@barRubikLbackLU
 . [878, 890, 891, 892](#)
 \side@barRubikRbackRD
 . [932, 944, 945, 946](#)
 \side@barRubikRbackRU
 . [822, 834, 835, 836](#)
 \side@barRubikTbackLU
 . [897, 909, 910, 911](#)

$\backslash\text{side@barRubikTbackRU}$	$\backslash\text{SquareFp}$ 1453	$\backslash\text{SquareSFp}$
. 841 , 853 , 854 , 855	$\backslash\text{SquareFs}$ . . . . .	. . . . . 2726 , 2727 , 2728
$\backslash\text{side@barT}$ 646,	. . . . . 1515 , 1516 , 1517	$\backslash\text{SquareSfp}$
647 , 648 , 665 ,	$\backslash\text{SquareFsp}$ . . . . .	. . . . . 2017 , 2018 , 2019
666 , 667 , 684,	. . . . . 1520 , 1521 , 1522	$\backslash\text{SquareSp}$ 1918
685 , 686 , 703 ,	$\backslash\text{SquareFw}$ 1472	$\backslash\text{SquareTB}$
704 , 705 , 722 ,	$\backslash\text{SquareFwp}$ 1493	. . . . . 2623 , 2624 , 2626
723 , 724 , 741 ,	$\backslash\text{SquareL}$ 1534	$\backslash\text{SquareTBp}$
742 , 743 , 784 ,	$\backslash\text{SquareLa}$ 1660	. . . . . 2628 , 2629 , 2631
804 , 923 , 924 , 925	$\backslash\text{SquareLap}$ 1681	$\backslash\text{SquareU}$ 2031
$\backslash\text{SL}$ 27	$\backslash\text{SquareLp}$ 1555	$\backslash\text{SquareUa}$ 2159
$\backslash\text{Sl}$ 27	$\backslash\text{SquareLs}$ 1618 , 2660	$\backslash\text{SquareUap}$ 2180
$\backslash\text{Sp}$ 26	$\backslash\text{SquareLsp}$ 1639 , 2671	$\backslash\text{SquareUp}$ 2075
$\backslash\text{space}$ 5	$\backslash\text{SquareLw}$ 1576	$\backslash\text{SquareUs}$ 2117 , 2682
$\backslash\text{Square}$ 2565 , 2578	$\backslash\text{SquareLwp}$ 1597	$\backslash\text{SquareUsp}$ 2138 , 2693
$\backslash\text{SquareB}$ 1184	$\backslash\text{SquareM}$ 1702 , 1973 ,	$\backslash\text{SquareUw}$ 2052
$\backslash\text{SquareBa}$ 1214	2006 , 2316 ,	$\backslash\text{SquareUwp}$ 2096
$\backslash\text{SquareBap}$ 1219	2327 , 2466 , 2477	$\backslash\text{SR}$ 27
$\backslash\text{SquareBm}$	$\backslash\text{SquareMB}$	$\backslash\text{Sr}$ 27
. 2398 , 2399 , 2400	. . . . . 2548 , 2549 , 2550	$\backslash\text{string}$ 1179
$\backslash\text{SquareBmp}$	$\backslash\text{SquareMBp}$	$\backslash\text{SU}$ 27
. 2403 , 2404 , 2405	. . . . . 2553 , 2554 , 2555	$\backslash\text{Su}$ 27
$\backslash\text{SquareBp}$ 1189	$\backslash\text{SquareMF}$	
$\backslash\text{SquareBs}$ 1204	. . . . . 2538 , 2539 , 2540	T
$\backslash\text{SquareBsp}$ 1209	$\backslash\text{SquareMfp}$	$\backslash\text{TB}$ 28
$\backslash\text{SquareBw}$ 1194	. . . . . 2543 , 2544 , 2545	$\backslash\text{TD}$ 28
$\backslash\text{SquareBwp}$ 1199	$\backslash\text{SquareMp}$ 1723 , 1984 ,	$\backslash\text{textCubieLD}$
$\backslash\text{SquareD}$ 1224	1995 , 2305,	. . . . . 39 , 1085 , 1103
$\backslash\text{SquareDa}$ 1350	2338 , 2455 , 2488	$\backslash\text{textCubieLU}$
$\backslash\text{SquareDap}$ 1371	$\backslash\text{SquareR}$ 1744	. . . . . 39 , 1085 , 1112
$\backslash\text{SquareDp}$ 1245	$\backslash\text{SquareRa}$ 1871	$\backslash\text{textCubieRD}$
$\backslash\text{SquareDs}$ 1308 , 2704	$\backslash\text{SquareRap}$ 1892	. . . . . 39 , 1085 , 1094
$\backslash\text{SquareDsp}$ 1329 , 2715	$\backslash\text{SquareRp}$ 1766	$\backslash\text{textCubieRU}$
$\backslash\text{SquareDw}$ 1266	$\backslash\text{SquareRs}$ 1829 , 2638	. . . . . 39 , 1085 , 1085
$\backslash\text{SquareDwp}$ 1287	$\backslash\text{SquareRsp}$ 1850 , 2649	$\backslash\text{textRubik}$ 25 , 1180
$\backslash\text{SquareE}$ 1392 , 1940 ,	$\backslash\text{SquareRw}$ 1787	$\backslash\text{textRubikB}$ 1184
1951 , 2360 ,	$\backslash\text{SquareRwp}$ 1808	$\backslash\text{textRubikb}$ 2756
2371 , 2510 , 2521	$\backslash\text{SquareS}$ 1913	$\backslash\text{textRubikBa}$ 1214
$\backslash\text{SquareEp}$ 1413 , 1929 ,	$\backslash\text{SquareSB}$	$\backslash\text{textRubikBap}$ 1219
1962 , 2349,	. . . . . 2731 , 2732 , 2733	$\backslash\text{textRubikBc}$ 2768
2382 , 2499 , 2532	$\backslash\text{SquareSb}$	$\backslash\text{textRubikBcp}$ 2769
$\backslash\text{SquareF}$ 1434	. . . . . 2022 , 2023 , 2024	$\backslash\text{textRubikBm}$ 2397
$\backslash\text{SquareFa}$	$\backslash\text{SquareSBp}$	$\backslash\text{textRubikBmp}$ 2402
. 1525 , 1526 , 1527	. . . . . 2736 , 2737 , 2738	$\backslash\text{textRubikBp}$ 1189
$\backslash\text{SquareFap}$	$\backslash\text{SquareSbp}$	$\backslash\text{textRubikbp}$ 2757
. 1530 , 1531 , 1532	. . . . . 2027 , 2028 , 2029	$\backslash\text{textRubikBs}$ 1204
$\backslash\text{SquareFm}$	$\backslash\text{SquareSF}$	$\backslash\text{textRubikBsp}$ 1209
. 2388 , 2389 , 2390	. . . . . 2721 , 2722 , 2723	$\backslash\text{textRubikBw}$ 1194
$\backslash\text{SquareFmp}$	$\backslash\text{SquareSf}$	$\backslash\text{textRubikBwp}$ 1199
. 2393 , 2394 , 2395	. . . . . 2012 , 2013 , 2014	$\backslash\text{textRubikCB}$ 2780

<code>\textRubikCBp</code>	2781	<code>\textRubiklp</code>	2747	<code>\textRubikSp</code>	1918
<code>\textRubikCD</code>	2776	<code>\textRubikLs</code>	1618	<code>\textRubikSR</code>	2632
<code>\textRubikCDp</code>	2777	<code>\textRubikLsp</code>	1639	<code>\textRubikSr</code>	1989
<code>\textRubikCF</code>	2778	<code>\textRubikLw</code>	1576	<code>\textRubikSRp</code>	2643
<code>\textRubikCFp</code>	2779	<code>\textRubikLwp</code>	1597	<code>\textRubikSrp</code>	2000
<code>\textRubikCL</code>	2770	<code>\textRubikM</code>	1702	<code>\textRubikSU</code>	2676
<code>\textRubikCLp</code>	2771	<code>\textRubikMB</code>	2547	<code>\textRubikSu</code>	1923
<code>\textRubikCR</code>	2772	<code>\textRubikMBp</code>	2552	<code>\textRubikSup</code>	2687
<code>\textRubikCRp</code>	2773	<code>\textRubikMD</code>	2515	<code>\textRubikSup</code>	1934
<code>\textRubikCU</code>	2774	<code>\textRubikMDp</code>	2526	<code>\textRubikTB</code>	2622
<code>\textRubikCUp</code>	2775	<code>\textRubikMF</code>	2537	<code>\textRubikTbp</code>	2627
<code>\textRubikD</code>	1224	<code>\textRubikMFp</code>	2542	<code>\textRubikTD</code>	2606
<code>\textRubikd</code>	2752	<code>\textRubikML</code>	2471	<code>\textRubikTdp</code>	2610
<code>\textRubikDa</code>	1350	<code>\textRubikMLp</code>	2482	<code>\textRubikTF</code>	2614
<code>\textRubikDap</code>	1371	<code>\textRubikMp</code>	1723	<code>\textRubikTFp</code>	2618
<code>\textRubikDc</code>	2764	<code>\textRubikMR</code>	2449	<code>\textRubikTL</code>	2582
<code>\textRubikDcp</code>	2765	<code>\textRubikMRp</code>	2460	<code>\textRubikTlp</code>	2586
<code>\textRubikDm</code>	2365	<code>\textRubikMU</code>	2493	<code>\textRubikTR</code>	2590
<code>\textRubikDmp</code>	2376	<code>\textRubikMUp</code>	2504	<code>\textRubikTRp</code>	2594
<code>\textRubikDp</code>	1245	<code>\textRubikR</code>	1744	<code>\textRubikTU</code>	2598
<code>\textRubikdp</code>	2753	<code>\textRubikr</code>	2748	<code>\textRubikTUp</code>	2602
<code>\textRubikDs</code>	1308	<code>\textRubikRa</code>	1871	<code>\textRubikU</code>	2031
<code>\textRubikDsp</code>	1329	<code>\textRubikRap</code>	1892	<code>\textRubiku</code>	2750
<code>\textRubikDw</code>	1266	<code>\textRubikRc</code>	2760	<code>\textRubikUa</code>	2159
<code>\textRubikDwp</code>	1287	<code>\textRubikRcp</code>	2761	<code>\textRubikUap</code>	2180
<code>\textRubikE</code>	1392	<code>\textRubikRm</code>	2299	<code>\textRubikUc</code>	2762
<code>\textRubikEp</code>	1413	<code>\textRubikRmp</code>	2310	<code>\textRubikUcp</code>	2763
<code>\textRubikF</code>	1434	<code>\textRubikRp</code>	1766	<code>\textRubikUm</code>	2343
<code>\textRubikf</code>	2754	<code>\textRubikrp</code>	2749	<code>\textRubikUmp</code>	2354
<code>\textRubikFa</code>	1524	<code>\textRubikRs</code>	1829	<code>\textRubikUp</code>	2075
<code>\textRubikFap</code>	1529	<code>\textRubikRsp</code>	1850	<code>\textRubikup</code>	2751
<code>\textRubikFc</code>	2766	<code>\textRubikRw</code>	1787	<code>\textRubikUs</code>	2117
<code>\textRubikFcp</code>	2767	<code>\textRubikRwp</code>	1808	<code>\textRubikUsp</code>	2138
<code>\textRubikFm</code>	2387	<code>\textRubikS</code>	1913	<code>\textRubikUw</code>	2052
<code>\textRubikFmp</code>	2392	<code>\textRubikSB</code>	2730	<code>\textRubikUwp</code>	2096
<code>\textRubikFp</code>	1453	<code>\textRubikSb</code>	2021	<code>\textRubikx</code>	2740
<code>\textRubikfp</code>	2755	<code>\textRubikSBp</code>	2735	<code>\textRubikxp</code>	2741
<code>\textRubikFs</code>	1514	<code>\textRubikSbp</code>	2026	<code>\textRubiky</code>	2742
<code>\textRubikFsp</code>	1519	<code>\textRubikSD</code>	2698	<code>\textRubikyp</code>	2743
<code>\textRubikFw</code>	1472	<code>\textRubikSd</code>	1945	<code>\textRubikz</code>	2744
<code>\textRubikFwp</code>	1493	<code>\textRubikSDp</code>	2709	<code>\textRubikzp</code>	2745
<code>\textRubikL</code>	1534	<code>\textRubikSdp</code>	1956	<code>\texttextsc</code>	15, 16
<code>\textRubikl</code>	2746	<code>\textRubikSF</code>	2720	<code>\TF</code>	28
<code>\textRubikLa</code>	1660	<code>\textRubikSf</code>	2011	<code>\the</code>	32, 45
<code>\textRubikLap</code>	1681	<code>\textRubikSFp</code>	2725	<code>\thislevelcount</code> . . .	53
<code>\textRubikLc</code>	2758	<code>\textRubikSfp</code>	2016	<code>\thislevelitem</code> . . .	52
<code>\textRubikLcp</code>	2759	<code>\textRubikSL</code>	2654	<code>\TL</code>	28
<code>\textRubikLm</code>	2321	<code>\textRubikSl</code>	1967	<code>\TR</code>	28
<code>\textRubikLmp</code>	2332	<code>\textRubikSLp</code>	2665	<code>\TU</code>	28
<code>\textRubikLp</code>	1555	<code>\textRubikSlp</code>	1978	<code>\typeout</code>	7, 10, 13

U		\underbrace 75, 77	\uy . . 425, 428, 429,
\U	25	\Up 25	431, 432, 434,
\u	28	\Urb 81, 111, 255, 419,	435, 438, 439,
\Ua	27	453, 667, 684, 925	441, 442, 444,
\Uc	29	\Urm 80, 110,	445, 448, 449,
\Ulb 81, 111, 251, 415,		248, 412, 443, 685	451, 452, 454, 455
447, 665, 705, 923		\Urt . . . 79, 109, 241,	
\Ulm 80, 110,		405, 433, 686, 722	X
244, 408, 437, 704		\Us 27	\x 28, 52, 56,
\Ult . . . 79, 109, 237,		\usefont 24, 25	62, 67, 1010, 1013
401, 427, 703, 724		\Uw 27	\xcount . . 53, 56, 62, 67
\Um 26		\ux . . 424, 428, 429,	
\Umb . . . 81, 111, 253,		431, 432, 434,	Y
417, 450, 666, 924		435, 438, 439,	\y 28, 1011, 1013
\Umm 80, 110, 246, 410, 440		441, 442, 444,	
\Umt 79, 109,		445, 448, 449,	Z
239, 403, 430, 723		451, 452, 454, 455	\z 28, 1012, 1013